A

GENERAL VIEW

OF THE

NATURAL HISTORY

OF THE

ATMOSPHERE,

&c. &c.

A

GENERAL VIEW

OF THE

NATURAL HISTORY

OF THE

ATMOSPHERE,

AND OF

ITS CONNECTION WITH THE SCIENCES OF

MEDICINE AND AGRICULTURE;

INCLUDING

AN ESSAY ON THE CAUSES OF

EPIDEMICAL DISEASES.

BY HENRY ROBERTSON, M. D.

VOL. I.

EDINBURGH:

Printed by Abernethy & Walker,

FOR W. LAING, A. CONSTABLE & CO. AND W. & J. DEAS, EDINBURGH; AND FOR CADELL & DAVIES, AND LONGMAN, HURST, REES, & ORME, LONDON.

1808.

TO

FIELD-MARSHAL,

HIS ROYAL HIGHNESS,

EDWARD,

DUKE OF KENT AND STRATHEARN,

EARL OF DUBLIN, KNIGHT OF THE MOST NOBLE ORDER OF THE GARTER AND OF S^t^. PATRICK,

&c. &c.

SIR,

IN presenting the following Work to Your Royal Highness, it would be injustice to my feelings, were I not to express myself highly sensible of the honour which Your Royal Highness has been pleased to confer on me by patronising it.

I am aware of the difficulties I encounter in submitting these pages to the observation of a Prince of Your Royal Highness's taste and discernment; but flattered by Your Royal Highness's condescension, I am proud of the opportunity of offering this tribute of respect to your il-

lustrious character: and I shall feel very highly gratified, if my labours appear to have any other claim to merit, in the opinion of Your Royal Highness, than what may perhaps arise from an attempt to investigate a branch of science of considerable importance.

Fully impressed with every possible sentiment of gratitude and respect, I have the honour to be,

SIR,

Your Royal Highness's most dutiful,

And most obedient humble servant,

HENRY ROBERTSON.

Edinburgh,
January 30. 1808.

INTRODUCTION.

THE earth is surrounded by an invisible elastic and gravitating fluid, which reaches to a considerable height above its surface. Although this fluid does not oppose any apparent resistance to the passage of the sun's rays, or to the motions of animals and other natural processes, it has nevertheless been ascertained to be of the most important and indispensable use, in the performance of the functions of the animal and vegetable economy, and to have the effect even of modifying the illuminating power of the sun.

The word Atmosphere is appropriated to distinguish this fluid, and it seems to have been originally suggested by the followers of an opinion, which prevailed in remote antiquity, respecting the nature and figure of its component particles.

The atmosphere is perceived to have a permanent influence over every part of the creation, although this does not seem to be equally powerful in every variety of matter; its effects being most conspicuously discerned in the two great classes of natural objects above mentioned, upon which it continues to act, under every circumstance and variety of organization, and, with a certain degree of temperature, is indispensably requisite for their immediate existence. The investigation of the properties of the atmosphere, may be therefore considered as affording a subject of the most interesting nature for the study of the general student, and deservedly claims the attention of professional men, as presenting a scope for research, by which the most useful knowledge may be acquired. The importance of this investigation has been accordingly inculcated even in the most remote ages, as forming a branch of science which, in its application to the purposes of life, is the most conducive to the comfort and interest of mankind.

A knowledge of the properties of the atmosphere, promises to confer benefits upon society of the most interesting nature, by enabling us to comprehend its power in varying the dispositions of different classes of mankind, and in accounting for the appearances of animals and plants, peculiar to different climates. There are diseases peculiar to every country, which are evidently occasioned by the influence of the air; and there are others which occasionally occur, seemingly common to mankind in general, which have been supposed to be propagated by the immediate influence of this fluid, in consequence of an alteration of its natural qualities, or its being mixed with certain matters possessed of peculiar properties. It is therefore evident, that the power of the atmosphere, either as a supposed cause of diseases, or as a powerful means of preventing and curing them, can only be properly determined by a scientific examination of its properties, and of its affinity to other matters. In this point of view, an acquaintance with the properties of the air, and its influence on living bodies, may seem to be particularly interesting to medical men; these are, however, equally important to every individual.

"Vivit et ætherias vitaleis succipit auras." *Luc. lib.* 2.

For this reason I have been induced to collect materials for the following work, which, with much diffidence, is now presented to the public.

The influence of the atmosphere is so various and complicated in many operations of art, as well as in the functions of the animal and vegetable economy, that to embrace its effects in general, would form a very extensive field of investigation: on that account, it is meant to limit the following observations, to the power of the atmosphere in the sciences of medicine and agriculture, although its effects in several manufacturing processes will be occasionally taken notice of. In this way, it is proposed to treat of the subject under the following heads:

The first embraces a discussion of the physical properties of the atmosphere: this part naturally includes an account of meteors, as wind, rain, aurora borealis, &c.; and, as the influence of light and heat are extremely important in varying these phenomena, a few general observations respecting their effects are premised, and in order to facilitate the comprehension of several of the most important doctrines that fall to be taken notice of. For a similar reason, an account of atmospherical electricity is likewise given, as many of the most frequent and alarming meteors seem evidently to depend on the influence of this fluid; and to these is subjoined an account of prognostics of the weather, so far as they have been ascertained.

The second part comprehends an investigation of the chemical qualities of the atmosphere: this embraces the subject of eudiometry, oxidation, combustion, &c.; with a view of the properties of its constituent principles, and of the condition in which they exist in the composition of that fluid.

The third and last part involves the investigation of the influence of the air in continuing the functions of animals and plants; the principal of which are respiration, vegetation, and the temperature of living matters; together with the changes it produces upon animal and vegetable remains, as in fermentations and putrefaction. This part likewise includes the influence of climate, or an investigation into the physical properties of the atmosphere, in regard to their effects upon living animals and plants; and as the qualities of the air are frequently varied by the admixture of foreign matters, a general view of the most remarkable of them is added: this more particularly embraces the powers of marsh miasma and contagion. It may appear that this part of the subject is too minutely discussed; but its importance is generally admitted, and, I trust, will plead my apology for the details it has been judged necessary to enter into in this investigation.

The atmosphere is never found pure, at least near to the earth's surface: it is there presented to our senses, loaded with various heterogeneous matters that are continually exhaled from the soil, and which are either soluble in the air itself, or assume the aëriform state at the common temperature of the climate. These exhalations are so very copious, that some celebrated men among the earliest writers on the subject of the atmosphere, have supposed that it is entirely composed of them,—an opinion which the discoveries of modern times have shewn to be incompatible with its nature. In the following investigation, the terms atmospheric air, and common air, are used synonymously, and designate that fluid as it is found in the regions near to the earth's surface; the term, atmospheric air, being understood to be the permanent basis of the atmosphere divested of every heterogeneus principle. In treating of the atmosphere, it is usual to make an arbitrary division of it into different regions: the inferior region, according to Pere Cotte, is that portion of the air which reaches from the earth's surface to the height of about two leagues; the middle region begins where the former terminates, and reaches to the supposed height of even eighteen or twenty leagues: the superior region then commences, whose height is indefinite. The word stratum is sometimes used synonymously with region; but, in general, it signifies a tract of the air similar in point of temperature and other properties: thus, the lower stratum of the air comprehends a tract reaching from the earth's surface to the height of 300 or even 500 yards.

CONTENTS

OF

VOLUME I.

PART I.

OF THE

NATURAL HISTORY

OF THE

ATMOSPHERE.

PART I.

CHAP. I.

OF THE GENERAL PROPERTIES OF LIGHT, HEAT, AND ELECTRICITY.

INDEPENDENTLY of exhalations from the earth's surface, atmospherical air is likewise intimately combined with certain proportions of heat, light, and electricity; and by some chemists its aërial form has been supposed to be occasioned by its union with the former of these fluids. But when these matters exist in the atmosphere in a free state, they appear to have a very active influence in bringing about changes in that medium: it seems therefore necessary to premise a few general observations respecting their influence on bodies in general, which will enable us to comprehend with greater facility the manner in which they affect the atmosphere.

It is not our intention to enter into a minute discussion of the effects of these matters: the following observations shall be therefore confined, as much as possible, to a relation of such phenomena as bear a reference to the general subject of our investigation.

The effects of light, heat, and electricity, are very similar in many respects, and their properties in general fully prove their materiality: they may be elicited from every kind of matter, and seem to exist frequently combined in the same body, one of them becoming occasionally, as it were, the cause of the appearance of the others, while the changes effected by them separately on different bodies, are sometimes very much alike. These circumstances have induced some philosophers to suppose light, heat, and electricity to be different modifications of the same matter; however, it will be afterwards perceived, that the peculiarities of each sufficiently distinguish them as distinct fluids.

The intimate particles of these fluids are of extreme minuteness, and seem to be equally possessed of the highest degree of elasticity; and this repellent property is not apparently destroyed, even when they are combined with other matters, a similar power being possessed, in such instances, by the compound. In consequence of the above-mentioned property, and their strong affinity for bodies in general, they are never found in an isolated or free state, and cannot therefore be subjected to examination. The properties, therefore, of light, heat, and electricity, can only be ascertained by the change produced by them in their union with other substances. The principal source of light and heat is known to be in the sun, and many think that he is also the great fountain of the electric fluid, and have gone so far as to impute the general effects of gravitation to this cause; but it has not been determined by any direct fact, whether or not this opinion of the origin of electricity be correct. It is however known, that electricity abounds in the earth and in the atmosphere, and, in short, in every sort of matter in which light and heat are likewise found to exist: there are even instances where they have all been elicited from the same body by the operation of the same cause, as in processes where much friction is employed, in combustion, &c. Electricity is excited in some matters, by exposing them to a higher temperature; and heat is perhaps produced in every electrical experiment. From these circumstances, the opinion of their identity has been considered as by no means incorrect. Light is almost always discerned in explosions of the electric fluid; and when this fluid is passed over two glass plates, including an intervening thin piece of metal, by means of a powerful apparatus, the primitive rays of light may be impressed upon them, in the same order as when analysed by the prism.

Having premised these general remarks on the nature of light, heat, and the electrical fluid, we shall now add a few observations on the properties of each of them individually.

SECT. I.

OF LIGHT.

It has been already observed, that the sun is the principal source of light, and that it is emitted by his rays to the surrounding planets: its motion is always in a direct line; and it is found by calculation to reach the surface of the earth in the space of about eight minutes, being at the rate of nearly 200,000 miles in a second: the direction and velocity of light is the same from every luminous body. Light possesses properties which sufficiently distinguish it from all other matters. Owing to the peculiar nature or disposition of the particles of certain bodies, the rays of light are allowed to pass through them unimpaired, and these bodies are thence denominated transparent: this property is enjoyed in the highest degree by the atmosphere, and other permanently elastic fluids, or gasses. In passing through any substance, the rays of light keep always in a straight line; but on leaving one medium, and entering another dissimilar in density, they are proportionally bent from their course, and are then said to be refracted. The refracting power of bodies generally corresponds with their density; with the exception of combustible matters, in which it is always greater. Thus, when the solar rays enter our atmosphere, they take a course different from their previous direction; and the degree of refraction varies according to the different degrees of density in its several strata. It has been likewise supposed, that the refraction of the luminous rays is increased in proportion to the quantity of inflammable matter the atmosphere contains. But, notwithstanding these circumstances, it does not appear that the direction of the luminous rays varies much from their point of incidence in passing through the atmosphere. The refraction of the sun's rays must be greatest in the stratum of air next the earth's surface, it being there denser and more impregnated with foreign matters, which are the sole causes of the refraction of the sun's rays in passing through this medium. Their refraction through this region has been supposed by Sir Isaac Newton to be nearly equal to that which takes place in their course through the whole atmospherical column, containing strata of different degrees of density; their aberration in passing through a dense air being corrected occasionally by their transmission through a stratum more rare. The rays of light are likewise capable of being reflected from bodies; and the angle of reflection is always equal to the angle of incidence. A ray is said to be perfectly reflected, when the whole of it is again thrown out, either as it struck the surface of any substance, or with but little variation. The rays of light are also occasionally inflected towards certain matters: this property depends considerably on the position of the bodies which are exposed to the rays of light, as well as to the affinity existing between the bodies and the luminous rays; and from this cause they are found in some instances to be deflected from matters. The rays of light can be also entirely stopped in their course by the intervention of a substance which has the property of absorbing them; and matters having this property are thence called opaque. The volume of a quantity of the luminous rays may be concentrated or diminished; and in like manner they are capable of being diffused over a larger space than the room which they naturally occupy.

These properties of light, together with the power it possesses of passing through a vacuum, distinctly prove the materiality of this fluid. Notwithstanding these circumstances, an opinion respecting its nature prevailed till the discoveries of Sir Isaac Newton, by which the phenomena of light were imputed to certain vibrations of a peculiar highly elastic fluid, pervading all space; but since the period when the experiments of this celebrated philosopher were made known, the distinct identity of light has been generally admitted. The reflection of the particles of this fluid from the furfaces of bodies, causes the sensation of vision. The extreme tenuity of the luminous particles, their strong repellent power, and their attraction for other matters, render it impossible to ascertain their specific gravity: this is probably beyond the comprehension of the human mind. On considering the amazing velocity of the rays of light, and their continued emanation from the sun, one would suppose, that were they possessed of gravity in a very slight degree only, matters against which they might happen to strike would be shivered by their impinging force. We have some idea of the tenuity of the particles of light, by admitting its rays through a hole pricked in a card by a needle, this being found of sufficient size to transmit, without confusion, all the luminous rays passing from the objects on the opposite side. Their minuteness is further shown, by the great distance at which rays emanating from a very small luminous object can be perceived, and by the immense space such bodies can illumine. There is a curious effect of light, probably first taken notice of by Bacon, that a chamber, or any other given space, illuminated by the emission of rays from a burning body, does not acquire a greater degree of illumination, however long the rays continue to be communicated to it: in this light differs from heat and electricity.

It has been ascertained by Sir Isaac Newton, that every ray, as it darts from the sun, is a compound of several others, which have uniformly distinct colours, differing individually from the original compound ray; and these simple or primitive rays are always seven in number. This fact is most easily demonstrated, by a triangular glass instrument called a prism; and the representation of the coloured rays is called a spectrum or image. When the compound ray is analysed in this manner, the simple rays always hold their places in the following order: red, orange, yellow, green, blue, indigo, and violet. The primitive rays are refrangible, in like manner as the compound rays, although in this respect they differ from each other; and they also possess the properties of reflection and inflection, with the exception, that these properties decrease according to the order enumerated; the red being possessed in a less degree of refrangibility, reflection, and inflection, the violet having these properties in the greatest degree; and it is in consequence of the difference of their refrangibility, that they are capable of being separated by means of the prism.

But Prieur, in the Annales de Chimie for

September 1806, adduces some experiments, from which he concludes, that the system of the coloured rays is reduced to three, of a particular unknown nature, being red, green, and violet. In combination, two of these produce the other coloured rays: thus red and green form yellow; the green and violet generate blue; the violet and red produce purple; the three together produce white; and the intermediate shades of colour originate in consequence of the proportionate quantity of either of these simple rays in the compound ray. It is to be observed, that this opinion seems to meet with confirmation, by what takes place in dyeing processes, and other attempts to produce what is called the compound colours, as orange, yellow, blue, indigo; these being likewise found to appear in the prism, intermediate to those which Prieur considers as the primary or simple rays.

Light, whether in the compound or simple rays, shows an affinity to some matters in preference to others, and enters into chemical union with them; in this way the varieties of colour are produced. It is confirmed by the experiments of Herschel, that the simple rays do not possess an equal power of illuminating bodies, the rays in the middle of the spectrum being most powerful in this respect; and those matters are most luminous, which reflect the whole, or greatest number of primitive rays.

The transparency of bodies has been already taken notice of, and is evidently owing to the free transmission of light through the interstices of their particles, the degree of affinity between them and the compound luminous rays being insufficient to cause their decomposition. Some matters absorb the whole of the luminous ray, reflecting none of the simple rays, and in this manner produce the sensation of darkness or black; other bodies absorb all the primitive rays but one, which is reflected, and thus give the peculiar colour, as red, green, violet, according to the colour of the ray which is reflected.

When light is strongly attracted by certain bodies, and enters into their composition, changes are thereby produced in their qualities, while, at the same time, the distinct properties of light disappear: in this way some of the acids are decomposed, and likewise the oxides of several of the metals. This change is occasioned by having a quantity of the oxygen gas extricated from them; this gas being usually separated from matters containing it when these combine with light. On the other hand, light is generally emitted when the substances with which it is combined unite with oxygen gas; but Fontana, by experiments, met with a different result, in the excretions of plants when exposed to artificial light: he says, that however bright or considerable the flame may be, it disengages from plants a mephitic or phlogisticated air; and that caloric, from whatever source it arises, produces the same effect. By the discoveries of Doctors Ritter and Woolaston, it has been found, that rays beyond the violet possess the de-oxidating power in the highest degree; and it decreases gradually through the spectrum towards the red; and, in short, all the chemical effects of light, in the most remarkable manner, arise in consequence of their impulse: they are, from this circumstance, named chemical rays. Light is supposed to excite the evolution of oxygen from growing plants; and it is also considered to be the chief cause of the peculiar green colour of their leaves. Its effects on animals are not less remarkable, it being a stimulus serving the most essential purposes in the healthy performance of their functions.

Light combines with some matters on being exposed to the sun's rays, in which it does not seem to occasion any alteration of their properties; and it is again emitted by these matters when carried into the dark: such substances are called Pyropheri. The light thus given out is generally similar to that to which the body has been previously exposed; though, from some late experiments, it has been found, that this does not always follow, the ray emitted being different from that which had thus combined with it. It would appear, from the more vivid colours of solid matters, that light unites with them in greater proportion, and in preference to such as are in a liquid or fluid state. Dr Darwin says, he has repeatedly observed, that the light of the evening is much greater than the light of the morning, at the same distance from noon: this, he supposes, is owing to the phosphorescent quality of almost all bodies, in a greater or less degree, which thus absorb light during the sunshine, and continue to emit it again for some time afterwards, though not in such quantity as to produce apparent scintillations.—See Note to Canto II. *Loves of the Plants.*

The sources of light are principally in the sun, matters in a state of combustion, animal substances in a peculiar state, decayed wood, pyrophori, and, according to Richard, light is frequently emitted from the surfaces of animals when overheated by coursing, as horses, hares, &c. The accumulation of heat in certain bodies is likewise productive of the same phenomenon: Light constitutes the brilliancy of the electric flash, and it is evolved by certain insects both terrestrial and aquatic. To enumerate all the sources of light would involve a very extensive investigation, as it enters into the composition of perhaps every substance: its appearance must therefore generally take place when a change occurs in their properties.

Many experiments have been performed, in order to ascertain the cause of the emission of light by animal and vegetable matters. Mr Boyle found, that rotten wood did not shine within the exhausted receiver of an air-pump, though it readily became luminous when the communication with the atmosphere was free. The same ingenious philosopher found, that dead fish, while in a similar state, did impregnate sea-water, salt and water, and some other liquids, with this luminous appearance; but that this property completely disappeared as soon as putridity had commenced. From these experiments, it seems probable, that the luminous appearance which is sometimes perceived in the water of the ocean may be frequently owing to a quantity of this matter being diffused through it, and not always to the existence of certain insects, as asserted by many of the academicians of Bologna.

The investigation of this subject has been recently resumed by Dr Hulme, and his experiments tend to corroborate the opinion just stated. Considering that the luminous appearance of these matters is destroyed by their being excluded from the access of the air, and also by immersion in certain liquors, as spirit of wine, diluted acids, alkaline solutions, and solutions of fixed air, &c.; it has been supposed, that the light thus emitted, appears in consequence of a certain degree of decomposition in the luminous substances themselves; but a complete elucidation of this matter has not been yet obtained. An explanation of the other sources of light will be occasionally mentioned afterwards, so far as they are connected with the subject of our investigation.

Light is regarded as one of the causes of heat; and as in other respects heat is intimately connected with this matter, we shall proceed to treat of its properties.

SECT. II.

OF HEAT.

HEAT, or Caloric, as it is now more generally denominated in philosophical writings, was long considered to be merely the effect of a peculiar vibratory motion in the minute particles of matter, though it had always been observed, that many phenomena depending on its influence, could not be explained on such an hypothesis. The late experiments of Herschel have confirmed a different opinion respecting the nature of heat, which is now generally adopted by the learned in every country. Herschel observed, in the course of performing some experiments on light, that the rays of the sun which produce colour, are always accompanied by others which have not this power: and he ascertained, that these have a much greater influence in exciting heat, than the visible rays. By this discovery it is found, that the solar rays are composed of rays, which, being capable of exciting the sensation of vision, are called luminous or coloured rays, and of others, which, having the property of raising the temperature of matters, are denominated calorific rays: the power of the latter is always greatest in the spectrum, at a small space beyond the red ray. Dr Herschel could not discover calorific rays beyond the violet, though that ray is also capable of producing a slight degree of heat, the force of which gradually increases towards the red. These, together with the chemical rays above mentioned, constitute the compound solar rays.

It has been found, that when the rays of the moon are concentrated by means of the most powerful lens, and thus thrown upon the bulb of a very delicate thermometer, no increase of caloric is thereby manifested: on the contrary, Richard affirms, that it produced a strong sensation of cold. A plate of glass allows the light to pass through it, while, at the same time, it stops the calorific rays, till the glass becomes heated or saturated with caloric to a certain degree. This fact was originally discovered by the late Professor Robison, and, connected with those ascertained by Dr Herschel, strongly militates against the supposed identity of heat and light. Fontana had likewise found, so long ago as the year 1781, that "la flamme passe dans l'instant à travers le crystal, comme la lumière (solaire); mais elle n'échauffe que tres tard les corps placés dernière le crystal;"—a fact which had been likewise remarked by Sennebier. It has been mentioned, that heat arises from sources which also give origin to light; it obeys similar laws of refraction, reflection, &c.; it moves at the same rate of velocity; and, like light, it is emitted from bodies in direct rays, and it does not increase the gravity of matters with which it combines, even when accumulated in them in the greatest possible quantity. But although, in many respects, it has a very considerable affinity to light, and arises from similar sources, it is equally well ascertained, that caloric has properties peculiar to itself, and that it is elicited in various chemical processes, where the slightest appearance of light has not been detected: it is, therefore, on the opinion of its identity as a peculiar matter, that we shall continue our observations respecting its effects.

Heat and cold are only relative terms, as applied to our own feelings, and signify different quantities of caloric existing in various matters, as indicated by our sensation. At a period not very remote, philosophers were accustomed to define cold, as a matter opposite in its qualities to those of heat: it was supposed to consist of what they denominated frigorific particles, which, in their combination with other matters, occasioned all the appearances that accompany matters at a low temperature. This hypothesis, although unsupported by facts, was most tenaciously defended by men of the greatest talents; and it even continued in vogue, till the discoveries of the effects of heat by Dr Black, towards the end of the last century; but, in proportion as the knowledge of the theory of heat, promulgated by that celebrated philosopher, became diffused, the supposition of cold existing as a peculiar matter has been given up.

Caloric, like every other matter, differs in its degree of affinity for other bodies; and though it has a tendency to come to an equilibrium, when bodies differing in qualities are exposed to its influence, it is perceived that these do not arrive at the same degree of temperature within the same period. Caloric readily enters some bodies, and combines with them, by which their temperature is increased, and their properties frequently changed; it is transmitted through others without increasing their temperature, in a degree corresponding to the intensity of the heat to which they are exposed. This difference of affinity has given rise to the division of matters into such as transmit, and such as conduct this fluid.

It appears, that with very few exceptions, the more dense the body, so much stronger is its powers of conducting heat. This property is considerably diminished in those which are rare: thus, the metals are found to be well adapted for conducting caloric; while liquids, and aëriform bodies, have this property in so slight a degree, that within these few years it was even denied they possess it. Matters which do not readily suffer any alteration in their component parts by a considerable increase of caloric, and whose volume is not greatly increased by its accumulation, are found to be excellent conductors; on the contrary, such matters as have their bulk easily affected by even slight additions of heat, or whose component parts are readily altered by combining with it, possess this power in a very low degree. But it has been ascertained by some late experiments of several ingenious chemists, that liquids, and even gaseous bodies, have a power of conducting caloric, though tardily. Caloric is transmitted through transparent bodies in a manner similar to that by which the luminous rays are allowed to pass through them; and it is not improbable, that the aptitude of bodies for transmitting caloric, increases in proportion to their want of power for conducting that fluid. For example, the atmosphere is a medium through which caloric is readily transmitted, although its conducting power be very low.

When caloric is accumulated in bodies, their bulk becomes thereby enlarged: thus a piece of iron, by being heated, has its dimensions increased greatly beyond its size, when at a moderate temperature. This effect of heat is greater in proportion to the rarity of the body: thus, it is found, that a degree of heat which is incapable of affecting the bulk of solid, or even liquid bodies, is sufficient to augment the volume of a portion of air in a very considerable degree. This circumstance is easily demonstrated, by holding to the fire a bladder that is lax, and containing but a small portion of air: in the course of a few seconds it becomes perfectly tense and elastic; and the expansion of the air within it may be so increased, even with a very moderate degree of heat, as to cause it to burst. The action of heat upon clay has been considered as an exception to this general effect, as it is observed to shrink in high degrees of temperature. Some have imagined that this anomaly is merely apparent; that it is to be explained by the great degree of attraction that subsists between that earth and water; and that the contraction of its dimensions at a great heat, is in consequence of the evaporation of water, with which it had been previously combined; while others, with seemingly better reason, have supposed it is owing to a certain degree of alteration in the minute particles of the body. But whatever may be the cause of this appearance, it has been applied to a most useful purpose in the arts, the late Mr

Wedgwood having contrived, in consequence of this property of clay, an instrument he calls a Pyrometer, as it enables us to ascertain degrees of heat of the greatest intensity, which could not be determined by any other means. When caloric is extracted from any substance, it contracts in bulk, and becomes heavier in proportion to its size: this effect is likewise more evident in fluid than in solid matters. Water is an exception to this rule: it has been found to expand when cooled below 40° degrees of Fahrenheit's thermometer; and its expansion continues to increase, till its temperature descends nearly to what is called the freezing point. From this effect of caloric on matters in general, the principles on which the thermometer is constructed are deduced. Before we proceed to mention any other effect which the matter of heat is capable of producing, it will be necessary to premise a general description of this instrument. For a history of the invention of the thermometer, and for an account of the various instruments of this kind now in use, we must refer to the works of Pere Cotte, of De Luc, and to the various systematic works on chemistry. The thermometer derives its name from its application in measuring different degrees of heat in bodies: it consists of a glass tube, of an equal caliber throughout, one of its ends being formed into a hollow ball, the ball, and about one-fourth of the tube, being filled with quicksilver; it is then to be exposed to a degree of heat sufficient to expel the air from the upper part of the tube; its open extremity is then to be hermetically sealed: in this manner the instrument contains only quicksilver, which occupies but a small portion of the tube. Quicksilver is generally preferred in the formation of the thermometer, on account of its great susceptibility of the general effects of caloric already mentioned, and being unalterable when exposed to considerable variations of temperature.

The instrument thus formed, is usually fitted to a scale on which the various degrees of temperature are marked; and these are determined in the following manner; the bulb of the tube being dipt into water while freezing, and allowed to remain till the quicksilver it contains becomes stationary, a mark corresponding to its height is made on the scale; and this point, in Fahrenheit's thermometer, is 32°, or the degree at which water always freezes. The ball of the thermometer is next to be plunged into boiling water, and a similar mark is again made on the scale, opposite to the point at which the quicksilver stands in the tube; this is numbered 212°, or the heat of boiling water. The intermediate space is divided into 180 equal parts: the portion of the tube below 32°, is also divided into

32 equal degrees, the undermost being marked 0° or zero; and the portion of the tube above 212° may be divided into any number of equal parts, but corresponding to the other divisions on the scale. The reason why the freezing and boiling heat of water are preferred for the purpose of forming the fixed points on the scale of the thermometer, is on account of the uniformity of the occurrence of these changes, whenever water has been deprived of, or has acquired, a certain proportion of caloric. There are thermometers formed of various liquids; as of coloured spirit of wine, linseed oil, and even air: these are generally graduated according to the fancy of the inventors, or the uses for which they are intended. The instrument of this kind most generally in use in Britain, is the one invented by Fahrenheit, which we have just described, and it is perhaps superior to most of the others, from the accuracy of its fixed points. Several other thermometers are formed on similar principles, and only differ in the division of the space between the two fixed points. One of these most generally in use, is that by Reaumur; the lowest point being marked zero; the highest, or that of boiling water, being 80°. There is another instrument of this kind, which is most frequently employed by the French chemists, and is called the Centigrade thermometer: the number of degrees into which the space between the highest and lowest points is equally divi-

ded, being 100; and on account of the equality of the numbers into which the space between the fixed points is divided, it seems the most convenient form of the instrument.

Matters can neither be made to combine with caloric, nor can they be deprived of it beyond a certain degree, without suffering a considerable alteration in their general properties. Heat entirely decomposes some, while its combination with others produces a complete change of form, without separating their component principles. Thus, when water unites with caloric even till its temperature is raised to 200°, it still retains its common liquid form; but when the heat is accumulated till its temperature arrives at 212° it then boils: an appearance, which is caused by a quantity of the liquid flying off in the form of vapour. Again, if water be cooled down till its temperature sinks so low as 32°, it then loses its liquid form, and is converted into a solid. It is to be observed, that a similar change takes place in every liquid, in consequence of the variations of temperature, though different liquids require different quantities of caloric to effect similar changes in their form.

Heat has a similar influence on solid bodies, rendering them fluid: thus, wax, and metals, exposed to proportionate degrees of heat, melt or become liquid, and resume their natural state on losing this quantity of caloric. In this way, caloric is understood to be the cause of fluidity in all bodies; and the permanent state of the aëriform fluids, is likewise imputed to their intimate combination with it. That various bodies usually appear in certain forms, either solid, liquid, or fluid, even when presented to the same degree of heat, is explained by the different capacities of different matters for caloric, and likewise by the greater or less intimate attraction between this fluid and their principles. Thus, a degree of heat which would hardly be sensibly indicated, when combined in a piece of iron, is found sufficient to melt an equal bulk of wax. Water requires a temperature equal to 212° to convert it into steam, while ether becomes aëriform at the common temperature of the atmosphere in summer, and can only be retained in its liquid state by the force of pressure. This general effect of caloric, is of the highest importance in elucidating the theory of many chemical processes. The cause why changes occur in the condition of bodies, by combining with certain quantities of heat, has been supposed by Dr Irvine to arise in consequence of a change of capacity for heat in the body acted upon, occasioned by the repellent power of the particles of caloric being sufficient to overcome the force of cohesion between the intimate particles of the body itself, or its affinity of aggregation. This theory agrees with what is known of the general properties of caloric, and does not materially differ from the theory of fluidity proposed by Dr Black,—a theory established on the result of the most ingenious and accurate experiments, and repeatedly confirmed by more recent observation.

Water is known to exist in three different states, solid, liquid, and aëriform; or, in common terms, ice, water, and steam or vapour. These states of this liquid differ from each other in consequence of their combination with different proportions of caloric. Thus, ice becomes water by the addition of heat, and vapour is converted into the liquid form, by being deprived of a quantity of that fluid. Ice, while it thaws, and until it be completely melted, never reaches an higher temperature than the freezing point, although the quantity of heat communicated to it may be sufficient to raise an equal weight of water to the boiling temperature: as this quantity of heat is not indicated by the thermometer, or in any other manner, it becomes a most interesting subject of investigation, in order to ascertain the manner how this quantity of caloric disappears on combining with the ice. Dr Black denominates this quantity of heat, "latent," because it cannot be detected by the thermometer, and as its effects are only visible in the changes produced by its union with the ice. There is not perhaps two bodies in nature who have the same capacity for caloric: the capacity of ice being less than that of water. When heat is accumulated in the former beyond 32°, its capacity begins to increase, and it therefore melts; the liquid which is thus formed, having its capacity increased, gradually absorbs the caloric, as it is communicated to the ice, which only unites with the quantity necessary to cause a change in its form. It is desirable to ascertain the precise point at which bodies change their form: this was first determined by Dr Black, in the case of water, and serves as the basis of his discoveries on the effects of heat. To a pound of ice at 32° he added an equal weight of water heated to 172°; the ice was thereby melted, but the temperature of the mixture did not rise above the freezing point, consequently 140° of caloric had disappeared. This determines the difference of the capacity of water to be to that of ice as 140° to 1°, which is also called its heat of fluidity; and it is in consequence of this difference of capacity between ice and water, that immediately before a fall of snow, and also during its fall, the temperature of the air generally becomes milder, the watery vapour existing in the atmosphere, giving out, as it freezes, the necessary proportion of caloric with which it was united in that state. And by the same theory it is likewise explained, why the air feels much colder when the frost on the surface begins to thaw; the melting ice thereby absorbing a quantity of caloric from the atmosphere and other matters, in consequence of its increase of capacity.

Water heated to 212° boils. This occurrence, it has been already observed, is occasioned by a part of it being gradually converted into steam or vapour, which rising through the water, causes the peculiar bubbling appearance as it mixes with the atmosphere, and which characterizes this process. Steam is equally transparent, and is possessed of greater elasticity than the atmosphere, at the same degree of temperature. It is capable of being united to indefinite proportions of caloric, without suffering any change in its constituent principles; though water, when exposed to the air, never acquires a higher temperature after having reached the boiling heat; nevertheless, when its communication with the air is carefully precluded, and a considerable pressure is at the same time applied, as in Papin's digester, it may be then heated till its temperature rises to 400°; but on allowing a communication with the air, its temperature immediately sinks to 212°, a considerable quantity of water, in the form of vapour, making its escape at the opening. By calculating the quantity of caloric that thus suddenly disappears with the water that goes off in vapour, and comparing it with the quantity and temperature of the water which remains at 212°, it has been found, that 940° of Fahrenheit are necessary to give water the condition of steam: this quantity of heat not being sensibly indicated in the vapour, shows the proportion of latent or specific heat it contains. On this theory, a satisfactory explanation is afforded of all the circumstances connected with the conversion of water into steam. During evaporation, there is always felt a degree of cold, in consequence of the absorption of heat from surrounding bodies, sufficient to give the water the form of vapour. On this principle liquors are cooled during great heats, by exposing them to the sun's rays, or a current of air: the vessels in which they are contained being kept constantly moist on the outside, the humidity, in being converted into vapour, extracts a necessary proportion of caloric from the liquor exposed to this operation. In this way, weak liquors can be frozen even within the torrid zone. It is owing to the absorption of caloric by the greater capacity of steam, that water, when it has acquired the temperature of 212°, never rises higher than this degree: any additional quantity of caloric it receives combines with the water, causing a greater proportion of it to be evolved. The correctness of this theory is likewise confirmed by what takes place in several manufacturing processes; the vapour being converted into the liquid state, while the caloric with which it had been united is set free: thus, in distillation, a process which is performed by putting matters diluted with water, from which any particular liquor is to be extracted by means of heat, into a vessel of a certain shape, called a still, having a cover so closely fitted, that no vapour can issue by the joinings: from this cover there is extended a long tube of a spiral form, called a worm-tube, which is immersed in a vessel filled with cold water, from thence called a refrigeratory: the spiral tube affords an outlet for the matters distilled; and these always enter it in the form of steam, which is condensed as it passes through that part of the tube which is surrounded with the cold water, and is in this manner more conveniently received in the liquid state at its external opening; but unless the water in the refrigeratory be kept constantly cool, by occasionally renewing it, it would very speedily acquire a degree of heat equal to the contents of the still itself: this increase of temperature arises from the caloric that had been combined with the vapour which has been condensed in the tube. In manufactories where great quantities of hot water are required, as in dyeing and bleaching, it has been found more expeditious and economical to convey steam into the vats, previously filled with cold water: being there condensed, it quickly raises their contents to the necessary degree of temperature. To this theory, also, the explanation of many processes occurring in the atmosphere is to be referred, as the warm sultry weather frequently experienced before rain, the coolness of the air after it has fallen, and the effect of evaporation in modifying the temperature of the air in warm weather and in hot climates.

These are the general effects of caloric which seem necessary to be mentioned in this place. Any other remarks respecting its effects will be farther illustrated, when treating of the sources of its origin. Besides being contained in the sun's rays, caloric is frequently produced in bodies by combustion, friction and percussion, electricity, and the effects of mixture. It has been long known, that the most intense degree of heat may be produced by concentrating the sun's rays. This was formerly imagined to be the consequence of the concentration of the luminous rays only; but, since the discoveries of Herschel, it seems probable, that this great degree of caloric may be owing principally to the power of the calorific rays themselves: otherwise, this experiment would afford a strong presumption of the identity of heat and light; as it is not readily perceived how the luminous rays alone should be a source of caloric, supposing these to be distinct fluids. According to this opinion, it must either be admitted, that the affinity between heat and light is so strong that they are never separated in the solar rays; or that caloric is elicited from bodies in proportion as these combine with the rays of light, and that this takes place in consequence of a new arrangement in their ultimate particles. Perhaps the concentration of the sun's rays may produce heat in both these ways. Its peculiar effects on matters in general prove it to be a fluid totally distinct from that of light, to which, however, it bears the strongest affinity.

As there is no condition of matter yet discovered which is entirely deprived of caloric, all bodies are therefore presumed to be combined with a portion of that fluid; and from the doctrine just stated, it will be readily perceived, that these are united with a greater or less proportion of it, according to the state in which they appear; solids having been uniformly found to contain least, liquids a greater proportion, and gaseous or aëriform bodies most of all. It likewise follows as a consequence, that whatever alters the general properties of any substance must have a corresponding tendency to change its capacity for caloric: thus, some matters acquire a greater power of combining with caloric, by undergoing a chemical alteration in their principles, and thereby have the power of absorbing heat from surrounding matters, according to the degree of alteration which takes place in them. Other substances, by a similar alteration, lose the degree of affinity for heat which they previously possessed; and therefore, a change in their composition liberates a quantity of caloric with which they had been united in their entire state. This takes place whether the effect be simply a change of the natural condition of the body, as from a solid to a liquid state, or when it proceeds so far as to occasion an entire separation of its component principles.

It is in this way we are enabled to explain the source of the caloric extricated from burning bodies; a portion of the atmosphere combining with the inflammable body, and assuming thereby another form, and, entering into other combinations, it suffers a corresponding change in its capacity for heat: therefore, in every instance of combustion, a considerable rise of temperature is the consequence. But this subject will fall to be more fully attended to afterwards, when we come to treat of the chemical properties of the atmosphere.

Friction, as well as percussion, are both considered as sources affording caloric. There is no circumstance better known than the possibility of hammering a piece of iron till it becomes red-hot. The extrication of heat by these means probably depends on causes similar to those we have stated under the head of combustion, and are owing to a condensation of the particles of the matter itself: thus, the specific gravity of metals has been found increased by hammering; it therefore follows, that a corresponding change in their capacity for heat must be the consequence.

The rise of temperature in consequence of the mixture of substances, is likewise to be imputed to a change of capacity in the compound; it being less than the aggregate of the separate capacities of its component parts. In this way, the heat emitted in many familiar operations may be illustrated, as in the solution of saline matters, the slaking of lime, &c. The whole or the greatest portion of the heat given out in the latter operation is extricated from the water as it enters into union with the lime; the quantity of caloric set free being the proportion necessary for retaining it in a state of fluidity. Water having a greater affinity for lime than for its caloric of fluidity, loses this portion of heat on being united with the latter; and the capacity for heat in the dry pulverulent mass formed by the combination being also much less than the sum of the capacities of the water and the lime in their separate state, a proportionate quantity of caloric is thereby set free. The same theory is applicable in explaining the evolution of caloric during the mixture of sulphuric acid and water: the specific gravity of the mixture being greater than the mean of the acid and water taken separately, its capacity for caloric is accordingly less than the sum of each of their capacities taken together; and consequently, the rise of temperature is owing to a proportion of the caloric being set free that was previously retained in these substances.

SECT. IV.

OF ELECTRICITY.

Electricity resembles caloric in many of its properties, and has its origin from several causes, as friction, combustion, liquefaction, coagulation, evaporation, and in the heating and cooling of bodies. It frequently increases the temperature of those substances through which it passes; and it is capable of setting fire to very inflammable matters. In its action on other bodies, electricity sometimes shows the effect of an intense heat, without raising their temperatures. The electric fluid can be elicited from a great variety of bodies by friction. In some matters it is always more abundant than in others: these are therefore called electrics; and the atmosphere is one of the most remarkable of this class. There are some bodies through which the electric fluid is conducted with facility, and others which do not possess this property: from thence, matters are divided into two general classes,—perfect conductors, and imperfect or non-conductors: amongst this last class electrics of every kind are enumerated. There are also two states or conditions in which the electric fluid occasionally exists in matters: one of them is usually called *plus*, or positive, when there is more of this fluid combined with a body than what it naturally contains; and a body is said to be in a *minus* or negative state of electricity, when a less quantity of this fluid exists in it than what constitutes its natural proportion. Electrics, whether in a positive or negative state, repel matters which are in a similar state of electricity; but those negatively charged attract such as are in a positive state, and *vice versa*. The union, in consequence of this attraction, produces a snapping noise, and a smart flash of light. Caloric has also the effect of changing the condition of electrics. Beccaria found, that a great many substances became phosphorescent after being heated, and that electricity produces in some degree a similar effect. Electricity seldom changes its condition in bodies suddenly, without causing an extrication of light; and, from experiments, Dr Priestley imagined it to be the cause of their transparency. The electrical fluid is emitted copiously by the earth in the process of evaporation; but Dr Priestley did not find that this process was hastened by an accumulation of electricity in water set to evaporate.

The proportion of electricity in the atmosphere during winter, appears at first sight to be much greater than what it contains during summer; and it has been ascertained to be at all times more copious in elevated than in low situations, it being more abundant on the top of the Alps than in the valleys; but Mons. Saussure could not detect electricity under trees, in crowded streets, or within doors. This ingenious philosopher has rendered it extremely probable, that the electric fluid forms a component part of water; and he very naturally supposes, that by this source the atmosphere is supplied with this fluid during evaporation. Mr Canton has likewise shown, that air, freed of moisture and heated, contains electricity in a negative state; that this fluid is positive in it when cool; and that the air suffers variations in its quantity of electricity, as it is condensed or expanded beyond its natural condition. Beccaria found, by experiments, that, during windy weather, the atmosphere gave no signs of electricity; nor when the sky was very clear, nor when covered with distinct black clouds that had a slow motion: but he always perceived signs of a moderate state of electricity in the air, but interrupted, when the weather was moist and not actually raining, and in a calm clear sky. In rainy weather without lightning, his apparatus was always electrified a little while before the rain, and during its fall; but it ceased to be affected a short time before the rain was over.

The Abbé Mazeas concludes, that in weather of equal dryness, the electrical state of the air is always the same; and he could not discern any signs of electricity during moist weather. The electricity of the air is always strongest during fogs; also after rain, snow, or hail, immediately after sun-set, and in frosty weather. M. Saussure has also observed, that just before sun-rise and sun-set, as also during night, electricity could always be discovered in the air; but he found it to be extremely irregular in stormy weather. The same philosopher has also ascertained, that this fluid is weaker in a serene summer, than during similar weather in winter: the electrical state of the air is then found to be always positive in the night, during the day, and when dew falls. From these experiments, and similar observations of Beccaria, Cavallo, and others, it has been concluded, that the atmosphere possesses a positive state of electricity almost at all times: however, Dr Paterson observes, that, "from air itself, not the smallest particle of electric matter ever comes; for there is reason to think, that air, independent of the substances with which it is impregnated, is unable to furnish an atom of this matter; and it is conjectured, that pure air and electricity are actually incapable of uniting."

M. Achard, in the Berlin Memoirs, taking notice of the disposition of the air to shed dew, found, that this condition, as also a sudden overcasting of serene weather, was always marked by variations in the electricity of the lower air.

As heat increases, and cold diminishes the solvent power of air, it follows, that the quantity of moisture remaining the same in both cases, its non-conducting power of electricity is in direct proportion to its heat. Vapour is a conductor of electricity, and so much the more perfect, as it is hotter: moreover, it contains and appropriates a considerable portion of the electric fluid; and, according to the opinion of the ingenious Dr Kirwan, electricity most abounds in the atmosphere when the temperature is highest: it is greatest in the vapour from land within the tropics, if not mountainous, than in that raised from the ocean. In temperate climates, in summer, marine vapours contain least; but in winter they contain more than those raised from off land; and in land, the vapours raised from mountainous tracts contain less than those elevated from the low grounds.

It would appear, from these observations, and especially from the experiments of Saussure, that the electricity of the atmosphere suffers a diurnal variation. The cause of this is still unknown; at the same time, there are some circumstances which render it probable, that it likewise depends on the influence of the sun in causing the evaporation of water. Beccaria imagined, that an highly electrical state of the atmosphere had an effect to lower the mercury in the barometer; and, according to the statement of Mr Maddison in the Philadelphia Transactions, a similar effect has been observed after the appearance of the aurora borealis,—a meteor now generally believed to be electrical. The lightning, so frequently perceived in the atmosphere, has been ascertained by Dr Franklin to be electrical: it follows the same affinity as electricity, and produces similar effects upon animals and vegetables. Lightning is most frequently the concomitant of thunder, though it likewise appears when no such storm takes place. In still warm evenings, it is frequently seen gliding through the air: this appearance is most frequent in autumn, and has been supposed to be the principal cause of blight in grain: such weather is said to be favourable to the growth of fungi; but with more certainty, it may be considered as the precursor of rain.

Electrical explosions have a peculiar smell; and the same sensation is perceived during the prevalence of lightning. Like electricity, it sets fire to straw, gunpowder, charred wood, and, in short, to every inflammable matter. It is probably owing to the sudden expansion caused by lightning in a portion of the air, that buildings of the greatest strength are thereby overthrown during thunder.

Thunder is an electric meteor: it is most frequent during summer in temperate climates; and in every latitude it is most frequent in that season when the greatest rains usually fall, and it prevails oftenest in countries where the rain is most copious. It likewise appears oftenest when the wind blows from a point which brings the greatest quantities of rain: it therefore rarely occurs in Britain when the wind is north or easterly. In the vicinity of Rome the winter is mild; and thunder is there common in all seasons. This meteor is by no means frequent in dry, parched situations, as in the deserts of Arabia, Lybia, in Egypt, and some districts in South America. The appearance of thunder is supposed to be occasioned by different contiguous strata of the atmosphere being at the same time differently charged with the electric fluid. The intervention of a cloud, or a current of air, so as to form the junction of these strata, produces an equilibrium in their electric condition, a circumstance which is announced by a previous flash of lightning, immediately succeeded by a loud noise, protracted by successive peals: this noise is continued, and repeated in proportion to the mass of air which thus tends to unite; the flash of light, and the succeeding report, are the circumstances which characterize this meteor. Some have supposed, that a portion of the vapour contained in the atmosphere, is decomposed during thunder, and that to this circumstance, the peculiar smell generally perceived in thunder storms has been imputed. This opinion has not, however, been confirmed byexperience; though, considering that it is observed, that thunder most frequently occurs over situations where evaporation is most copious, and that it is also rarely experienced in places where that process goes on but sparingly, it seems probable, that the electric state of the atmosphere depends in a considerable degree on the quantity of vapour it contains. The dreadful effects that so frequently ensue in consequence of thunder, has not yet been accurately accounted for. Formerly these were supposed to have been occasioned by a communication of electric fluid from the earth to the atmosphere; and in other instances the electricity was thought to have been impelled from the air to the earth; but it does not seem probable, that either of these occurrences are common; nor has the action of electricity, in its destructive effects during thunder, been so satisfactorily explained, as by the theory proposed by Earl Stanhope. It has this to recommend it, that it agrees better with common appearances in electrical experiments, than any other that has yet been advanced on the subject. On discharging a powerful electrical apparatus, there seems to be a direction of the electric fluid, called the returning stroke, as it appears in a directly opposite course, and immediately after the principal discharge operates. By a judicious application of this fact to the appearances which occur during thunder, his Lordship has been thereby enabled to trace the course of the electric fluid, in instances where it has proved fatal.

CHAP. II.

OF THE PHYSICAL PROPERTIES OF THE ATMOSPHERE.

SECT. I.

OF THE COLOUR, FLUIDITY, DENSITY, AND ELASTICITY OF THE ATMOSPHERE, AND OF ACOUSTICS.

THE atmosphere, as it immediately surrounds us, appears entirely colourless; but taking a more extensive view of the horizon, it is perceived of a peculiar blue tint, which it possesses always in fair weather, and which seems to deepen in shade the higher we ascend in it. An investigation of the cause of this peculiar colour, has engaged the attention of several philosophers of celebrity. The opinion which Muschenbroeck has embraced respecting this question, continued long to prevail. He imagined, according to Otto Guerick and others, that it was owing to the combination of the luminous rays with a very deep shade existing behind the atmosphere, where the visible rays are neither refracted nor reflected. Yet the favourers of this hypothesis have never been able to point out the situation of this space, nor have they ever advanced any argument that could render its existence even probable. Fabri supposes, that the colour of the atmosphere is occasioned by the reflection of the blue ray, by means of the foreign matters at all times floating in it; an opinion which is likewise ingeniously supported by Mr Delaval in the second volume of the Manchester Memoirs; but although this theory is assumed from principles more philosophical than the former, still it is impossible to reconcile it with the observations of Saussure, who always perceived the colour of the air deeper on the summit of the Alps than in the valleys, although in the higher regions it is much drier, and more free of impurities. But this fact militates irresistibly against the theory of Saussure himself regarding this question; as he supposes the blue colour of the sky arises in consequence of the reflection of the blue ray from the aqueous vapour which at all times abounds in the atmosphere. And were either of these theories correct, it naturally follows, that the colour should be proportionally deeper in those strata of the air nearest the earth, and when the air is most loaded with vapour and extraneous fluids: but daily experience shows us, that either of these conditions of it produces a contrary effect. When the vapour of water exists in the atmosphere in an highly elastic state: its transparency and colourless appearance is then most remarkable; and when the vapour is in a more dense form, as in clouds, the atmosphere is always proportionally obscured, and the clouds themselves are perceived to assume occasionally different hues, as milk-white, red, purple, very dark blue, green, and even violet, according to their density and position with regard to the sun.

The opinion of M. Mariotte on this question, next claims our attention. He shows, by experiment, that the atmosphere possesses a blue colour, independently of all foreign matters existing in it; that it acquires this tint, by having the property of reflecting the blue ray only; and that it does so most powerfully when in its purest state. This theory has been supported by the more recent observations of Professor Eberhard of Berlin; and it certainly accords better with general appearances than any of the others that have been suggested.

From what has been already stated of the nature of colours, when treating of light, it will be readily comprehended, that as the atmosphere, from its tenuity, can only reflect a small proportion of the blue ray, its peculiar colour can be only discerned when the reflection is returned from an immense space, and from air in its purest condition. For these reasons, the atmosphere, as it immediately surrounds us, appears entirely divested of colour; and when it happens to be loaded with a variety of extraneous matters, these always assume the tint of that ray to which they have the slightest affinity. Air, much impregnated with elastic vapour, is even more transparent than common air; that fluid being of still greater tenuity, it therefore reflects a smaller proportion of the coloured rays. It is probably owing to this cause, and to the continual elevation of vapour from the earth's surface, that, during dry weather, objects can be discerned at a greater distance, and seem occasionally to suffer a variation in their usual appearances. This theory seems likewise to receive confirmation, by finding that the atmosphere is always much darker in the reflected colour, when it blows from a point where it is most dense and freest of vapour, as during a north or east wind; and that it appears more transparent when blowing from a westerly point over Britain.

The atmosphere, in every condition, possesses an high degree of mobility: this property seems to be owing to the minuteness of its intimate particles, their interstitial distances, and to the degree of repulsion natural to them, in common with the rarer fluids. In consequence of this property, the atmosphere is found to answer the most beneficial purposes in the general economy of the universe. This susceptibility of motion of the air, from the slightest impulse, by preventing any portion of it from becoming stagnant, and by thus occasioning a continual change in its position, serves to transport the various animal and vegetable exhalations, which, by stagnating in the vicinity of their sources, would speedily become highly noxious, but being carried to a distance, they prove innocuous, even frequently beneficial, in other processes of nature. The motion of the air has evidently a tendency to rise upward: this direction seems to be occasioned by the reflection of the calorific rays of the sun from the earth's surface: the lower stratum of air becoming thereby more heated, and being proportionally rarefied, it overcomes the pressure of the superincumbent strata, and naturally ascends: this effect is likewise increased by the elasticity of the vapour continually rising from the surface; the tendency of the air to ascend, must therefore be greater during day. The mobility of fluids correspond with their degree of rarefaction. It seems probably owing to the greater tenuity of the atmosphere in the higher regions, in consequence of the diminution of pressure, that its motion is there always experienced to be greater, being commonly agitated and in a stormy condition.

Although the atmosphere be apparently of an uniform density throughout, it has been ascertained, that at different heights it varies considerably in this respect, and it differs at the same height in different latitudes. The causes which chiefly produce variations in the density of the air, are temperature, pressure of incumbent strata, and extraneous bodies existing in it. In the former chapter, the manner how caloric operates, in causing the expansion of fluids, was pointed out: it will therefore be readily understood, why a stratum of air, at an high temperature, will be less dense than a similar stratum, whose temperature is low. The air being also an highly elastic fluid, its density is consequently augmented by pressure; therefore the stratum of air nearest the earth, would be at all times proportionally more dense, were the temperature equal throughout, owing to the superincumbence of the superior strata. It has been known, since the days of Sir Isaac Newton, that the particles of a body possessed of a repellent force reciprocally proportional to the centre of their distances, will compose a fluid whose density will be in a degree corresponding to the weight by which it is compressed. It is to this force the atmosphere owes its elasticity; and were it not for the gravity it possesses, and its attraction to the earth, it would occupy an indefinite space: like every other fluid, its elasticity is in the inverse ratio of its density. The elasticity of the air is likewise, according to Wolfe, in direct ratio of the weight with which it is loaded, and it is rarefied or diffuses itself in the direct ratio of the quantity of heat which acts on it; and like every other fluid, it constantly tends to an equilibrium.

By the experiments of General Roy and De Luc, it has been demonstrated, that the density of the air diminishes in a degree corresponding to its altitude; and that this diminution takes place in a ratio corresponding to geometrical progression, the ascent being in arithmetical progression. This is the general opinion now entertained on the subject. At one time the observations of Bouguer raised some doubts as to the accuracy of this calculation; but it has been more recently discovered to agree with the experiments performed by Saussure *junior*. In this way, if, at the height of three miles, the air be only half as dense as it is at the surface of the earth, at the altitude of six miles, it should be four times more rare. But as we proceed in this investigation, we shall nevertheless find, that this calculation is not without its exceptions.

Common air is the least compressible of any of the artificial gases; being, according to Fontana, in a ratio to this property of vital air as $\frac{1}{50}$, to azotic gas as $\frac{1}{100}$, to hydrogen gas as $\frac{1}{80}$, to nitrous air as $\frac{1}{105}$, to carbonic acid gas as $\frac{1}{80}$, &c. The following table, on the foregoing principles, is copied from the 15th volume of the Philosophical Magazine.

The decreasing density of the air:

At $3\frac{1}{2}$ miles	the air is	2	times rarer.
7		4	
14		16	
21		64	
28		254	
35		1.024	
42		4.096	
49		16.384	
56		65.536	
63		262.144	
73		1.048.576	

In the 25th volume of the Journal de Physique, Fouchy gives the description of an instrument he invented for measuring the density of different strata of the atmosphere. It consists of a thin hollow glass globe, suspended to the extremity of a delicate balance, to the other extremity of which there is appended a small weight, that moves in a groove formed in a piece of wood, that is placed perpendicularly, and upon this there is marked an index, by the help of which the difference in the density of the various strata of the atmosphere is indicated. As the glass globe must at all times displace a volume of the air equal to its own bulk, which being occasionally of different degrees of density from the causes above mentioned, the difference will be precisely indicated by the motion of the weight in the groove. Saussure *junior* has likewise given the description of an instrument of the same kind, which he thinks is better adapted for being carried about, and with which he conducted his experiments on this subject; for an account of it, see 36th volume of the Journal de Physique.

The atmosphere has been perceived to be increased one-fifth in density, by the greatest cold of the climate of Paris, and to lose one-seventh of its mean weight by the greatest heat of the same place. Mr Boyle condensed the air to one-fifteenth of its common bulk, without producing any other change in its properties. He ascertained, that the density of the air is greater in serene weather, and greatest when charged with clouds and vapours. The same ingenious philosopher supposes, that air may be dilated to 10,000 times its natural bulk. Sir George Shuckburgh shews, that every degree of heat beyond 60°, increases its volume $\frac{1}{81}$ part. And from the recent experiments of Mr Dalton it has been ascertained, that aërial fluids in general acquire an uniform degree of expansion, under an equal degree of pressure, at every temperature. From these experiments it appears, that the atmosphere is capable of any degree of condensation or expansion, without suffering an alteration in its form or composition.

There are a variety of experiments, conducted by the most eminent philosophers, with a view to ascertain the precise degree of expansion which the atmosphere suffers at different degrees of temperature. This forms an investigation of the utmost importance, in order to insure success in our researches into the general properties of the atmosphere: it is confessedly a question extremely difficult to be resolved with accuracy: on this account, the results of the various experiments undertaken with the view of determining it, are by no means found to be uniformly the same. For many particulars of the most interesting nature respecting this question, we refer to General Roy's papers in the Philosophical Transactions 1777; Saussure sur l'Hygrometrie; De Luc, Recherches sur les Modifications de l'Atmosphere; Priestley on Air. We select a Table intended to show the Expansion of the Atmosphere, and what are called the Artificial Gases, at different degrees of temperature, from experiments by M. Du Vernois, as related by Morveau in the 1st volume of the Annales de Chimie; this being perhaps equally correct as any of the others, the experiments from which it is deducted being apparently very simple, and consequently susceptible of greater accuracy. The table is calculated by the scale of Reaumur's thermometer, of which 1 degree answers to nearly $2\frac{1}{4}$ of a degree of Fahrenheit.

It is to be understood, that air, like every other fluid body, undergoes a progressive expansion, or becomes more dilatable by the communications of equal portions of caloric, according to its previous degree of expansion and temperature; but M. Du Vernois found all the artificial gases differ in this respect. The experiments were performed by means of a retort filled with air, and placed in a vessel containing pounded ice: he thrust into the ice a thermometer, so that its bulb should be on a level with the centre of the vessel containing the air. After this arrangement, the apparatus was placed in a furnace, to which heat was applied: from the vessel containing the air, there issued a bent tube, whose point was next conveyed below a graduated measure filled with quicksilver, and placed in a mercurial trough of nine inches diameter. By this means M. Du Vernois was enabled to observe the slightest dilatation of the air, at certain degrees of heat, which was accordingly indicated by the sinking of the mercury. The degrees of expansion which took place from the freezing to the boiling point of water, are accordingly enumerated in the following table.

TABLE of the expansions of common air, and of the principal artificial gases, from the point of congelation to the boiling point of water, and of the entire quantities of expansion within these points.

	From 0 to 20°.	From 20to40°.	From 40 to 60°.	From 60 to 80°.	From 0 to 80°.
Common air dilates	$\frac{1}{12.67}$	$\frac{1}{5.61}$	$\frac{1}{2.49}$	$\left(\frac{1}{3.57}\right)$	$\frac{1}{1.067}$
Oxygen gas	$\frac{1}{22.12}$	$\frac{1}{4.92}$	$\frac{1}{1.53}$	$\left(3 \times \frac{1}{1.73}\right)$	$4 \times \frac{1}{1.09}$
Nitrogen gas	$\frac{1}{29.41}$	$\frac{1}{5.41}$	$\frac{1}{1.82}$	$5 \times \frac{1}{572}$	$5 \times \frac{1}{1.062}$
Hydrogen gas	$\frac{1}{11.91}$	$\frac{1}{6.92}$	$\left(\frac{1}{6.85}\right)$	$\left(\frac{1}{58.82}\right)$	$\frac{1}{2.55}$
Nitrous gas	$\frac{1}{15.33}$	$\frac{1}{9.00}$	$\frac{1}{3.739}$	$\left(\frac{1}{6.88}\right)$	$\frac{1}{1.65}$
Carbonic acid gas	$\frac{1}{9.049}$	$\frac{1}{5.099}$	$\frac{1}{2.31}$	$\left(\frac{1}{3.69}\right.$	$1 \times \frac{1}{106.3}$
Ammoniacal gas	$\frac{1}{3.58}$	$\frac{1}{1.75}$	$1 \times \frac{1}{1.35}$	$\left(3 \times \frac{1}{4.69}\right.$	$5 \times \frac{1}{1.248}$

Mr Dalton, however, says he has found, that the calculations of Du Vernois are erroneous in the higher degrees of temperature; that, on the contrary, those of Saussure, Berthollet, &c. are tolerably correct; and he seems to think, that the error must have arisen from not having kept the apparatus and materials free from moisture, Mr Dalton having found, that "for any given expansion of mercury, the corresponding expansion of air is proportionally something less the higher the temperature." But notwithstanding the approved accuracy of Mr Dalton's experiments, we are induced to suppose, that any error existing in the experiments of Mr Du Vernois, from the cause he assigns, must have a proportional effect throughout the whole.

In confirmation of Mr Dalton's opinion, Guy de Lussac has ascertained, by a great number of experiments, that oxygen, azote, hydrogen, and carbonic acid gases, are dilatable in an equal degree, from the freezing to the boiling point of water; and he concludes, that all gaseous matters undergo an equal degree of dilatation at equal degrees of temperature, and that, between the points above mentioned, each of them dilates $\frac{100}{246.66}$ for every degree in the centigrade thermometer. He agrees with Dalton, that the variations perceived by Du Vernois in the higher degrees of temperature, must have been owing to humidity contained in the air; and that there is likewise an error in the higher point of his table, in consequence of the diminished elasticity of the vapour or air in the balloon, by the quantity having passed over into his receiver. Perhaps some small error may have arisen from this source; but, if the theory of Lussac and

Dalton be correct, we cannot perceive how a portion of vapour should operate in varying the result. The following is the table of Lussac on the expansion of different gases, from the freezing to the boiling point of water.

Of 100 parts	Degree of dilatation.	Difference.
	Parts.	
Of atmospheric air,	37.50	
— hydrogen gas,	37.52	× 0,02
— oxygen,	37.43	0.02
— azote,	37.49	0.01

In many particulars, Lussac's experiments accord with those performed by Mr Dalton, whose mode of operation is so extremely simple, that their accuracy has not been called in question: nevertheless, the subject appears to merit still a careful examination; the result thus afforded being totally different from that which arises from the expansive power of heat upon solid or liquid bodies: thus, metals of nearly the same specific gravity suffer different degrees of dilatation, on being exposed to the same temperature; and the same circumstance might be expected to take place in the gases also. On this account, we have judged it proper to state the matter as ascertained by different experiments.

Mr Murray of Edinburgh has accounted in a very ingenious manner for this apparent anomaly in the expansion of gaseous bodies. It is

D 4

found, that all matters do not expand equally by definite increments of caloric. This evidently arises from a difference in the degree of attraction that subsists between their intimate particles. In solids, the expansion is less than in liquids; in both it varies according to their densities, or the force of the affinity of aggregation which is to be overcome by the elastic particles of caloric. In gaseous bodies, this force of cohesion between their intimate particles does not exist; consequently, the whole power of the caloric communicated to them will be exerted in causing their expansion, which Mr Murray supposes must in this manner take place in an equal degree in all of them; as their aggregate affinity is equally overcome in their natural state. But, if we can confide in the accuracy of the preceding table of Fontana on the different degrees of compressibility of the different airs, a considerable objection will present itself against the conclusiveness of this explanation. At any rate, granting that Mr Murray's opinion is correct, it certainly does not warrant the conclusions of Lussac and Dalton against Du Vernois' experiments, as caloric must have equally affected the expansion of vapour as any of the gases with which it happened to be mixed.

There are many familiar operations which demonstrate the elasticity of the air. The above-mentioned experiments, by which its rarefaction and compressibility are demonstrated, are founded on this property. The explosions of an air-gun, the operation of a common bellows, and the theory of sound, or acoustics, elucidate this principle. This property of air is also most elegantly demonstrated, in the working of every description of water-works, where, by its elasticity, the water is projected to the height of thirty feet or more; and it is in consequence of this, that Mr Boyle found the air compressible in proportion to the force of the pressure it is subjected to. A portion of the air, confined by means of a strong degree of pressure, has been found to regain its usual volume, after having been confined in a state of the greatest density for several years. This is entirely to be ascribed to the natural degree of elasticity it possesses. This elastic property of the atmosphere may be readily demonstrated, by plunging a large drinking-glass into a bason of water, with its mouth inverted: in this way it is filled with air, which, by its resistance, prevents the admission of the water into the glass; but, at the same time, the volume of the air will be perceived to be diminished according to the pressure upon the glass, and the deeper it is thrust into the water. The condensation of the air in this manner is increased, according to the density of the medium employed to confine it: thus, if the bason be filled with quicksilver, its condensation will be still more remarkable, and its expansion will likewise become more evident, in proportion as the pressure is removed. In this manner, the elasticity of the air is shown at any degree of temperature. It is by this property also, that a vessel capable of holding a given quantity of air, at a high temperature, is found to be equally filled with a fourth or a sixteenth of that proportion, even when its temperature is cooled below the freezing point. In like manner, during the operation of exhausting the receiver of an air-pump, if the working of the machine be stopt before all the air is drawn out, it will be perceived, that what remains is much more rare, and that it occupies the whole space of the receiver as completely as before.

But the elasticity of the atmosphere is still more distinctly shown, by placing the bladder of a small animal, half filled with air, within the receiver: according as the pressure of the atmosphere is removed, by exhausting the machine, the confined air expands, and distends the bladder; and the pressure being entirely removed, the bladder is sometimes ruptured in consequence of the elastic force of the air within it. In this way, it is perceived that the atmosphere, like every other gaseous body, has its elasticity increased or diminished in a degree corresponding to the extent of the room occupied; and, for this reason, the lower strata of the air must be most elastic, this property decreasing as we ascend.

Those who are accustomed to go across the Alps, are aware of the excessive mobility and elasticity of the atmosphere. In the spring season, when the snow begins to melt, considerable masses of it frequently tumble down from the mountain tops, to the imminent danger of the unwary traveller. To prevent any disaster from this occurrence, it is usual to fire a pistol in passes where snow-falls are most likely to happen; for, without this precaution, even a very moderate sound of the voice has been known to give an impulse to the air, which has loosened the snow from the precipices overhanging the roads.

The theory of sound depends likewise on the properties of the air which we have just mentioned. It is distinctly shown, that sound is propagated by means of the atmosphere, as no sound is transmitted from the exhausted receiver of an air-pump; and when a piece of clock-work, so regulated that the hammer continues to strike the bell, is confined in this machine, the sound is perceived to become gradually more weak, in proportion as the air is exhausted from it, and at last entirely to cease. Sound is communicated by producing a peculiar vibratory motion in the air, which is continued in a circular direction from every point of its origin. This motion can be perceived, by ringing smartly a common table-bell, or by friction along the brim of a large drinking-glass containing a quantity of water. Sound is propagated at the rate of 1142 feet in a second, or 13 miles in a minute; and all tones or degrees of sound move with equal velocity. A whisper flies with swiftness equal to the report of the most powerful artillery; which is in proportion to the motion of a brisk wind as 50 to 1.

Clear distinct sounds are supposed to be emitted by sonorous bodies of an uniform figure, while harsh, obtuse, or irregular sounds, are occasioned by bodies irregular in figure, or of unequal density: but sounds must be always regulated according to the impulse given to the atmosphere; for a similar sound will not be produced by the same instrument in different states of tension, nor if the degree of force applied be different. The state of the atmosphere itself has the most powerful effect in causing variations of sound. Sound is always louder when the weather is warm and serene, and is weakest when the barometer stands low; but it is loudest in a cold dense state of the air, and is more dull in rain, or in snowy weather, though M. Lambert says, that damp air only deafens, but does not retard the progress of sound. All degrees of sound are loudest and most distinct during night. This is perhaps owing, in a great measure, to the stillness of the atmosphere in that season; its motion being greater in the day-time, and in summer than in winter. This motion always occasions a peculiar noise, of strength in proportion to the season of the year or time of the day. Sounds are propagated farther by the vicinity of the sonorous body to a medium of greater density than the air: thus, thunder is rarely heard above six miles off; while the report of the artillery at the siege of Metz by Charles V. was distinctly heard forty leagues distant. Derham gives an instance, where the human voice was heard at the distance of several miles: but the noise occasioned by battles at sea have been audible at the greatest distance. The Tartars, and other nations of similar manners, are aware of this effect; and, by laying the ear close to the ground, they can announce the particular route of their tribes and cattle at a great way off. Sounds seem to be propagated in a direction tending to rise upward. This is owing to the diurnal motion of the air from the surface: hence it is found easier to communicate an intelligible sound to a person elevated above the speaker, than to render it equally distinct, with the same degree of exertion, to one placed below.

It is owing to the great velocity by which sound is propagated, that it is not frequently lost in the motion of the wind, which rarely happens, though wind frequently renders it very indistinct; but a gentle breeze seems to favour its continuation, if blowing from a point of the compass in a line with the sonorous body to the point of hearing: when the air blows in a contrary direction, a slow continued breeze is as great an obstacle to the propagation of sound, in opposition to its current, as the greatest storm.

Sound is always increased, by communicating the vibration through dilated tubes; and from this property, the instrument called a speaking-trumpet has been invented. Kircher supposes, that its effect is owing to the number of vibrations that are communicated to the air from the sides of the tube by reflection; and that these reflections conspiring to propagate similar pulses, increase the force of the sound; the increase of the number of pulses increasing the points of new propagation. The effect of this instrument is greatly augmented by the diminution of the lateral, and consequently the increase of the direct expansion and velocity of the included air. An echo is the principal effect of reflected sound, and it has been imagined to be merely the original vibration of the air repercussed from a concave surface, or when the bodies it strikes against are elastic. It has been found, that the reflection of sound, like that of light, is always equal to the angle of incidence, though the reflection of sound must depend greatly on the nature of the reflecting body. Thus, substances that are more elastic, have probably this property in greatest perfection. Sound being interrupted by hills, walls, houses, woods, and the like, gives occasion to the formation of an echo. It is found, that this variety of sound never occurs at sea, nor in an open plain country. The sound of an echo moves with a degree of velocity equal to that originally communicated by the sonorous body.

But although the report of artillery, or any other percussion of the atmosphere, does not give rise to an echo either at sea or in a plain country, nevertheless the peculiar rumbling noise of thunder is the same every where. This circumstance has been attempted to be accounted for, on the idea that the sound is reverberated from different strata of clouds. But as this peculiar noise takes place when the air is apparently of an uniform density, and as an echo does not follow the report of cannon at sea, however cloudy the atmosphere; for these reasons the following theory is subjoined, as being the most probable explanation of this phenomenon, and is promulgated by M. Monge in the Annales de Chimie, vol. v. p. 268. He endeavours to shew, that thunder is in every instance accompanied with the sudden condensation of vapour, of which it is probably the cause. He therefore supposes, that the rolling noise of a thunder clap, is occasioned by the impetuous motion of the air rushing in from all sides, to fill the void occasioned by the condensation of the vapour it contained; and it is in every respect similar to the noise that occurs in drawing a cork, or which follows the smart stroke of a whip upon the air. These properties of reflected sound, give an explanation of the cause of whispering galleries. There are many remarkable echos in every country; at Louvain in Flanders, Kilarney in Ireland, Woodstock in Oxfordshire, where seventeen syllables are repeated during day, and twenty during night. There is also a building in the vicinity of Milan, which reflects sounds more distinctly, and in greater number, than any other situation of a similar description; a smart noise being distinctly reverberated about three-score times. Kircher supposes it is owing to the vibration being returned by two parallel walls, which is thus reciprocally repercussed, till the impulse becomes too weak to produce any sound.

The gradual decay of the original impulse causes a corresponding diminution in the intensity of sound, and at length it ceases to produce any effect whatever. The decay of sound has been variously calculated on mathematical principles; but having no measure to ascertain the gradations of sound, the result of these calculations has been found to vary in every instance. From what has been mentioned respecting the influence of the air in propagating sound, it will be readily understood why much furniture in a room deafens the sound, by checking the free vibrations of the air; and on the same principles it is ascertained why vaulted rooms, alcoves, domes, and other concave pieces of architecture, increase the sound, in buildings intended for public orations.

It is well understood, that a room of an eliptical form has the property of reflecting sounds in the most remarkable degree: the tremulous rays of air leading from the point of percussion, follow the same angle in their reflection to any other point, and form a focus directly opposite. In this way it is understood why a person, standing on one side of such a building, can hear distinctly words pronounced in a whisper by the person opposite; and which cannot be heard by another person, standing in the same room, at a distance from the wall, and who happens to be without the range of the angle of the sound's reflection.

By an accurate attention to the minute variations and inflections of sound, people that are blind have been known to acquire a degree of knowledge sufficient to enable them to perambulate the most crowded cities, and even to enjoy the exercise of riding on horseback. By the same talent they are also enabled to recognise their former acquaintances, after a considerable lapse of time. There is a beautiful account of such circumstances, in the Lettres Persannes of Montesquieu, and 1st volume of the Manchester Memoirs.

SECT. II.

OF THE GRAVITY OR WEIGHT OF THE AIR, AND OF VARIATIONS OF THE BAROMETER, AND THEIR CAUSES.

IT has been already observed, that the atmosphere, like every fluid, tends always to an equilibrium: this it does, in consequence of being possessed of gravity or weight; a quality it has in common with matter in general.

The pressure of the atmosphere being always towards the surface of the earth, it will therefore have a constant tendency to acquire a level at the superficies: but as the density of the different regions of the air diminishes according to their degrees of elevation, its upper strata must therefore be in a state of the greatest rarefaction. Owing to the tenuity of the particles of the atmosphere, it is discovered to occupy the interstices of almost every other body. It has been found to penetrate the deepest mines, while it reaches to an immense distance above the tops of the highest mountains,—appearances which can only be explained as the effects of its specific gravity, and its properties as an elastic of the highest power. Before the gravity of the air was made known, it was usual to describe every appearance that takes place, in consequence of this property, by an hypothesis of the most gratuitous description: it was imagined, that all matter had an antipathy to a void space, and this innate abhorrence was on that account denominated *horror*, or *fuga vacui*. And to prevent the occurrence of an empty space, it was supposed, that the atmosphere occupies every interstice of sufficient size to admit its particles. In this way the consequences supposed to follow the event of a vacuum being formed, were prevented. The gravity of the atmosphere is familiarly demonstrated by means of a common syringe: while the nosle remains open, the piston can be worked with facility: this arises from the pressure of the air upward, being equal to the pressure from above: but if the piston be pushed completely down, and in this state the nosle be made to press firmly against the point of the finger, so as to exclude the access of the air, a very considerable resistance will be experienced, at every attempt to draw up the sucker: the body of the syringe being thus formed into a vacuum, the under part of the piston having no opposing fluid to counterbalance the superincumbent gravity of the air, the whole weight of the atmospherical column bears upon its upper part, and thus opposes a resistance to its ascent. As the gravity of the atmosphere is most generally determined by means of the barometer, it is necessary to premise a general description of that instrument, so that the subsequent investigation of this subject may be comprehended with greater facility.

The form of the barometer in general use, consists of a glass tube of about thirty-two inches in length, of an uniform cavity throughout; one of its ends being hermetically closed, is called the upper extremity; the opposite or under end, is formed into a cup or hollow bulb, having a communication with the atmosphere: the tube and bulb being filled with quicksilver, by closing the orifice with the thumb, till the instrument is reversed, the air is thus completely expelled from it; and on again placing the tube upright, with the cup undermost, a quantity of the quicksilver runs out: the portion that remains, continuing at a certain height in the tube, is found to correspond with the gravity of the atmosphere, and its height varies according to the state of the weather. A scale is generally placed towards the upper end of the tube, opposite to the top of the column of quicksilver: on this scale the different degrees are marked, the tube being divided into inches and parts; but owing to the variety of causes producing changes in the gravity of the air, it is found impossible to adapt an accurate scale for indicating the precise change of the weather.

There is a considerable variety of the form of the barometer, both for philosophical and common purposes, as a weather-glass; but however much they differ in form, they are all constructed upon the general principles we have laid down: but for a more particular account of this instrument, the systematic works of Pere Cotte, De Luc, and the Philosophical Transactions, must be referred to. The reason why a quantity of the quicksilver escapes from the cup of the barometer when it is placed upright, and that what remains continues at a certain point, is owing to the gravity of the atmosphere bearing on the base of the column of quicksilver, being only capable of supporting it at a certain elevation; the height of the mercury in the barometer, therefore, corresponds to the actual gravity of the atmosphere; and its variations from this point, arise in consequence of some previous change in the weight of the air.

In every country, and in every season, the mercury in the barometer has nearly one mean point, in situations on a level with the ocean; but it varies considerably from this point, by whatever occasions a change in the density of the atmosphere. The weight of the air, on a level with the sea-shore, is ascertained, by means of the barometer, to correspond to about thirty inches of mercury: this fact has been determined by Bouguer in South America; by Captain Phipps in N. lat. 80°; by Sir George Shuckburgh in the south of Europe, and in the English Channel; and it has been confirmed by the experiments of the learned in every part of the world. The point at which the quicksilver usually stands, by a calculation from its highest and lowest degree of elevation, is called its mean point; and the extent of the space between the points of its greatest depression and of its highest rise, is called the range of the barometer.

The barometer is always perceived to sink somewhat, on ascending from the sea-shore, and this takes place in proportion to the height of the interior. Thus, on the summit of a mountain of two or three thousand feet of ascent, the mercury is perceived considerably lower than the point at which it stands in the valley. On this principle, the barometer has been employed to determine the elevation of places above the level of the sea; and it has even been applied, on the same principle, to ascertain the height of the atmosphere itself. A Mr Sinclair is said to have been the first person in this country who employed the barometer for this purpose: his experiments were conducted so long ago as 1661. It is now generally agreed, that the method of determining the height of places by means of the barometer, is equally correct, as the admeasurement conducted on geometrical principles, and it has the advantage of being more expeditious: but there are several circumstances that necessarily require attention, in reducing this experiment to a satisfactory degree of accuracy. Though the gravity of the atmosphere is known to be nearly the same under the equator, as in the temperate zone or within the polar circles, still changes of temperature occurring in particular regions, must have the effect of rendering it partially more dense and heavy when the heat is diminished, or more light and rare when acted upon by an increase of temperature. As has been already observed, the atmosphere at great heights is considerably more rare, for which reason the rise or fall of the mercury in the barometer will not be so great, through an equal space, in such elevated places, as is observed to happen nearer the level of the ocean. In calculating the heights of places by means of the barometer, it is essentially necessary to be acquainted with its corresponding fall at various heights, and at different degrees of temperature of the air. Sir George Shuckburgh conducted the greatest number of experiments with a view to ascertain this point, and the following table is drawn up from the result of his labours.

Thermometer.	Feet.	
32	85.86	The volume of one-tenth of an inch of quicksilver on the barometer, expressed in feet in the atmosphere, when the barometer stands at 30 inches, according to the different temperatures.
35	87.49	
40	88.54	
45	89.60	
50	90.66	
55	91.72	
60	92.77	
63	93.82	
70	94.88	
75	95.93	
80	96.99	

The above table corresponds with similar experiments, performed by the late Dr Walker, Professor of Natural History at Edinburgh. He found, that about 90 feet of elevation accords with $\frac{1}{10}$ of the mercury in the barometer, in the ordinary temperature of the climate of this country during summer. But within the tropics, near to the line, the barometer has been observed to sink, for every 200 feet of elevation, only one-half the length it is found to descend in climates approaching the latitudes towards the poles. Upon the data of the foregoing table, the heights of the following places have been determined by means of the barometer.

Places.	Height in feet above the level of the sea.
Arthur's Seat, near Edinburgh, -	796
Highest Pentland Hills, - -	1700
Ben Lomond, - - -	3180
Bennevis, - - - -	4283
Tinto, - - - - -	2342
Shehallion, - - - -	3461
Calton Hill above Leith Pier, -	350
Cheviot, - - - -	2382
Snowdon, - - - -	3555
Mont Blanc, - - -	15,303
(by De Luc, it is 15,662)	
Ætna, - - - -	10,954
Vesuvius, - - - -	3938
Cross of St Peter's above the Tiber,	502

Places.	Height in feet above the level of the sea.
Iron gallery over the dome of St Paul's, - - -	281
Highest point of the Appenines,	8397
Pié d'Ossano, one of the Pyrennées,	11,700
Peak of Teneriffe, - - -	15,396
Peruvian Mountains, - - (their summit 20,000)	19,242

It has likewise been discovered by M. De Luc, from experiments performed at the bottom of a deep mine in the Hartz, that the barometer indicates the gravity of the atmosphere, in these situations, in like manner as it does on the tops of mountains. Indeed, in every situation and variety of climate, it will be found, that the mechanical properties of the atmosphere are uniformly obedient to the same laws.

From the above calculations by Sir George Shuckburgh, Mr Dalton has ingeniously deduced the following theorem, whereby he is enabled to calculate the height of the barometer at different elevations, and which affords the following table. Let $H =$ the height of the barometer below in inches, $b =$ the number of feet *per* table as before, $p =$ the perpendicular elevation of the upper barometer in feet, $y =$ the height of the mercurial column in inches : then we obtain this theorem : $y = \frac{600\,b - p}{600\,b - p} \times H$.

Elevation of the barometer above the sea, in English miles.	Height of the mercurial column of the barometer in inches.			
	Above the equator.	Above the north of England.		Above the north pole.
		In summer.	In winter.	In winter.
0	30.00	30.00	30.00	30.00
2	20.55	20.10	19.58	18.81
4	13.61	12.96	12.24	11.19
6	8.66	7.98	7.26	6.24
8	5.25	4.65	4.03	3.19
10	3.00	2.52	2.05	1.45
12	1.58	1.24	.93	.56

The above table is reduced on the supposition, that the mean heat at the earth's surface under the equator is 84°; in the north of England, during the hottest summer months, 60°, and for the coldest months in winter 35°; the mean annual temperature at the north pole being 31°.

Notwithstanding the ingenious calculations that have been undertaken on purpose to determine the height of the atmosphere, both from observations made with the barometer, as well as from calculations founded on geometrical principles, the question still remains undecided. It would be an endless and unprofitable task, to enter into a detail of the inquiries that have been made in this investigation: it appears merely necessary to relate, in a concise manner, the principles which have served as a basis for calculating the elevation to which the atmosphere rises above the earth, by means of experiments performed with the barometer; and to compare the results thus afforded with the deductions drawn from other sources. Supposing, according to Sir George Shuckburgh's table, that the barometer falls $\frac{1}{10}$ for every 87 feet of ascent; therefore, 300 times 87 makes the elevation of the atmosphere reach five miles: but this can only be determined with accuracy by ascertaining the density of its different strata, and the proportion of the fall of the mercury to a proportionate degree of elevation in different latitudes. The altitude of the atmosphere has been likewise calculated, by the height of the barometer being taken in arithmetical progression, the height of the air being in harmonic progression; but this method is especially objectionable, as it is liable to error from innumerable causes which cannot be prevented. M. Mariotte having ascertained the difference between the density of air and mercury, under the pressure of the atmosphere at the earth's surface, and its consequent dilatation at different heights, calculates, that the entire altitude of the atmosphere reaches to about 15 French leagues. But neither of these calculations corresponds with what is observed of the sinking of the mercury at very great heights, its descent not having been in proportion to the supposed altitude of the atmosphere.

Another method to determine this question has been attempted, by taking an observation of the degree where the rays of the rising and setting sun begin to be refracted: this occurs, when that luminary is 18° below the horizon. From this observation, it has been supposed, that the height of the atmosphere is at least equal to 20 French leagues. But even this amazing height does not correspond with calculations performed on similar principles, for the purpose of ascertaining the height of fireballs, the auroræ boreales, and other similar meteors, which are imagined to move within the verge of the atmosphere, but at a height greatly exceeding that which is afforded by this calculation. To what degree of elevation the very thin rarefied atmosphere extends, is not easily ascertained; but the superior regions of the air are certainly much higher than what can be determined by the barometer, or mathematical calculations, founded upon the supposed variations in its degrees of density. Besides the range of the barometer, there are many other proofs of the effects of the gravity of the air. The boiling of water on a level with the ocean always takes place at the temperature of 212°; but, at an elevation of a few thousand feet, the same change takes place at a much lower degree of heat; and when the pressure of the air is entirely removed, water boils at a temperature so low as 70°.

The following table is taken from the observations of Sir George Shuckburgh on this subject, and are the result of experiments he performed, in a journey over the Alps.

TABLE *of Observations on the Boiling Point of Water.*

Place of observation.	Height of the barometer in inches.	Heat of boiling water.
Bologna,	30.21	213.5
Geneva,	28.60	210.4
Modane,	26.61	207.3
Lannebourg,	25.75	205.1
Mount Cenis,	24.03	201.2
Ditto,	23.91	201.1

M. De Luc has also conducted several experiments on the same subject, which nearly coincide with the above.

Every liquid boils, or is converted into vapour, at a temperature peculiar to itself; but this may be varied, by diminishing or increasing the pressure of the surrounding air. This is shown, by boiling a small quantity of water, or any other liquor, in a Florence flask, the mouth of which must be well corked and secured with leather during the ebullition: the flask being then taken from the fire, its contents will cease to boil; but the process immediately recommences when it is plunged in a bason of cold water, and it again ceases on being exposed to heat. The theory of this process is explained in the following manner: When the water boils, a quantity of it is converted into steam; the orifice of the vessel being carefully stopt in this state, a portion of vapour is thereby confined over the surface of the boiling liquor: thus, while it continues at an high temperature, the pressure occasioned by the force of the steam prevents any more from being formed; therefore, the liquor does not appear to boil, though its heat be greater than the boiling temperature; but the flask being plunged into cold water, a quantity of the steam is thereby condensed, which causes a void in its upper part; therefore, the liquor continues to boil, while it retains a degree of heat sufficient to convert it into vapour in a vacuum, or till the formation of that fluid is again too forcibly resisted by the pressure of the steam thus generated.

It is found, that 100 cubic inches of atmospherical air weigh 31 grains. Considering the immensity of space which the atmosphere occupies, it will be perceived by this circumstance, that it must press upon the earth's surface with a prodigious weight. Its exact degree of pressure has been estimated at $14\frac{3}{4}$ pounds averdupoise upon every square inch. At first sight, it is difficult to conceive how animated beings are enabled to resist the pressure of this enormous burden; but as the gravity of the air presses equally on every side, as well laterally as downward, the injuries that would have otherwise occurred by it are thus prevented. There being 144 inches in a square foot, the atmosphere necessarily bears upon that space with a weight of 2088 pounds; and reckoning 12 square feet to the extent of the surface of a middle-sized man, it must therefore press upon his body at the rate of 25,056 pounds, amounting to more than eleven tons. In a similar manner, the entire pressure of the atmosphere upon the earth is estimated at 11,642,019,840,000,000,000 pounds,—a weight far beyond the reach of human comprehension. These data thus afford a calculation, which is rather to be considered as a proof of the enormous burden of the atmosphere, than as an accurate definition of its extent. In consequence of the gravity of the air, any resistance to its current, as in walking or riding, adds greatly to the fatigue of such exercise. A stream of air of seven feet square, nearly equal to half the extent of the body of an ordinary sized man, moving at the rate of only twenty feet in a second, adds greatly to the pressure; and the friction thereby occasioned raises a heat and redness of the skin, and frequently a feeling of heaviness and inclination to sleep. The pressure of the atmosphere produces many advantages of the highest importance in the economy of nature: it assists the circulation of the fluids in animals and plants; irregularities in their growth are thereby restrained:

this is shown, when the uniform pressure of the atmosphere upon the surface, is excluded by the partial use of any piece of dress, which, by producing this effect, tends to induce deformity, and irregularity in their growth: thus, man is better shaped, when accustomed to active pursuits, than such as are confined by sedentary professions. The gravity of the atmosphere is in other respects necessary in the performance of several of the animal functions, as in respiration, sucking, speaking, &c.; for unless the air had been possessed of gravity, these and other offices could not have been performed. It is this property of the air which prevents exudation of liquids from culinary and other utensils; and innumerable other benefits accrue from it in the arts.

The range of the barometer becomes the next subject of inquiry, and it is a question of very high importance in an investigation of the natural history of the atmosphere, as it leads us to consider those causes which produce partial changes in the gravity of this fluid. In tropical countries, the range is less than in climates towards the poles. By this it is to be understood, that the barometer never rises so high, nor sinks so low, as in other climates. From the tropics the range becomes gradually greater, and is greatest from about the 38th to the 50th degree of latitude. From this last degree, the changes of the barometer do not materially increase, and are nearly the same even in high northern climates. This opinion is not what is generally entertained, it being commonly asserted, that the range of the barometer increases from the equator to the poles; but it is advanced here on the authority of the late Professor Walker, and because it seems to accord with the tables of the range of the barometer in different countries given by Pere Cotte in his Treatise and Memoirs on Meteorology; and it likewise receives confirmation from the remarks on the climate of Russia, related by Dr Guthrie in the Edinburgh Philosophical Transactions: besides, when the causes of the variations of the barometer come to be considered, it will appear that this is the consequence that may be expected to result from their influence. By inspecting the tables of Pere Cotte above mentioned, it is perceived, that the range of the barometer at places in the 60° of N. lat. is not greater than in others, many degrees nearer to the tropics: thus, at Meaux, Utrecht, Zwanenburgh, &c. the variation is even more than at Abbo in Finland, or St Petersburgh.

Dr Guthrie found, that the barometer stood as in the following table, at a situation 20 feet higher than the level of the Neva, and 6000 feet from its falling into the Gulf of Finland.

For the six winter months, November, December, January, February, March, and April, which make 181 days of the common year.

At highest,	28° 87	commonly in Jan.
At lowest,	26° 99	oftenest in Nov.
Difference,	1° 88	

Mean between the extremes, 27° 93.

Mean height, 28° 02 Paris inches.

It stands 95 days above 28 inches, and 86 days below it.

For the six summer months, May, June, July, August, September, October, which make 184 days of the common year.

At highest,	28° 47	oftenest in May.
At lowest,	27° 50	oftenest in Sept. or Oct.
Difference,	97	

The mean between these extremes is 27° 96.

The mean height, 28° 04 Paris inches.

Its height for 107 days is above 28° inches, and for 77 days below it.

In the above, the scale is divided into Paris inches and hundred parts.

The same circumstance is confirmed by the experiments of Euler, as related in the second volume of Pere Cotte's Mémoires sur la Meteorologie. The greatest mean height of the barometer at Petersburgh during seven years, 1772-1778, amounted to 28° 8, and the lowest mean for the same period was 27° 2.11; the former occurred in the month of December, the latter in February. The same philosopher gives a very ingenious table in the fourteenth volume Nova Act. Petropol. which shows the range of the barometer at six different places, from the 51° N. lat. to the 68° N. lat. inclusive; and in no instance does the difference between the highest and lowest line greatly exceed an inch. The experiments were conducted during the whole of May 1769, and include an extent of observation of about 4000 miles.

As we proceed in this investigation, it will be perceived, that the range of the barometer does not exactly correspond in places similarly situated in every respect, and even at a few leagues distant: thus, the variations are not the same at Lisle and Brussels, at Meaux, Paris, and Vire in Normandy, even where the circumstances of situation nearly agree. But although an exact correspondence in the barometer, placed at distant situations, does not take place, nevertheless similar changes, though not corresponding in degree, do occur, even in the most distant places. The precise extent of these distances has not been ascertained; but such have been observed to happen in places 400, and even 600 miles distant. These variations have been supposed to agree nearly in point of time; this at least was observed in experiments conducted at Paris and Geneva for three years, in which period there was but one instance of exception. Although the column of the atmosphere be proportionally shorter in winter, yet it has been found, that the variations of the barometer are more frequent in that season every where.

The variation of the barometer is greater in mountainous countries and in islands. Its range is likewise greater on the continent of America, and in the north-east provinces of Asia, than in corresponding latitudes in Europe; and in every situation the range is greater the nearer the sea-shore. Thus, M. Ramel found the mercury in the barometer always stood lower in Provence than at Marseilles,—places where the difference of elevation is extremely trifling; thus, in the latter situation, the mean height of the instrument has been observed to be 27°, while in Provence it stood 28° all but two lines.

At Quito, the range does not exceed one line: this place is about 9000 feet above the level of the ocean, where the variation is frequently to the extent of three or four lines. At Peru, its greatest variation does not exceed the third of an inch; at Calcutta, it is about half an inch; at Naples, N. lat. 40° 55′, it is about one inch; at Dover, N. lat. 51° 8′, it is about 1½ inches; and the mean range over the whole of Britain does not exceed that proportion. At Williamsberg, in Virginia, lat. 27° 20′, the annual range is somewhat more than an inch; it is the same at Genoa, lat. 44°. At Paris, lat. 48°, the variation is about 1¼ inches. At Zurich in Switzerland, N. lat. 47°, and Marseilles, N. lat. 43°, the range in both places is about the fourth of an inch; at Arras, N. lat. 50°, and Bourdeaux, N. lat. 44°, it is about one inch; at Padua, N. lat. 45°, it is somewhat more than one inch; at Lyons, in the same degree of latitude, it is only about $\frac{10}{12}$ of an inch. The above examples furnish an undoubted proof of the effect of local situation in causing variations on the barometer. The greatest height the barometer was perhaps ever known to rise in this island, was observed by Sir George Shuckburgh in 1778: the mercury then stood at 30° 940′. And Mr Townly of Lancaster, in 1703, observed the mercury to be stationary so low as 27° 390′, which is the lowest it ever was perceived to be in this country.

By experiments performed by M. Laval on the top of St Pilon, a mountain in the neighbourhood of Marseilles, 300 feet high, he found, that the barometer varied but 1¾ lines, when the variation at Marseilles amounted to 2¾ lines.

It has been observed, that the highest extreme of the barometer occurs frequently in December or January; and it has been likewise observed, that the low extreme is most generally experienced in these months. From general causes which affect the range of the barometer, it appears, that the greatest fall of the mercury occurs most frequently when an extraordinary rise has preceded that occurrence. By observations conducted at Paris for twenty years, from 1699 to 1718 inclusive, ten out of eleven of the lowest falls were in January and December; the eleventh occurred about the middle of November.

Besides the variations which are called annual, as being deduced from observations continued throughout the year, the barometer likewise suffers variations which may be called diurnal, as being completed within the period of twenty-four hours. By experiments performed at Mexico by Don Alzaté, it appears, that the quicksilver stood always higher in the barometer in the mornings and evenings than at midday, or at three o'clock in the afternoon. His observations were taken at seven in the morning, at noon, at three in the afternoon, and at six in the evening.

There are some observations, greatly resembling these, related by Dr Balfour, in the Edinburgh Philosophical Transactions. He found, that almost without exception, the quicksilver fell between ten at night and six in the morning; between six and ten in the morning, it as constantly rose; between ten in the morning and six at night, it progressively fell, without a single exception; and, lastly, between six and ten at night, the barometer rose progressively, without any intermediate falling. The experiments on which these observations were made, he conducted during his residence at Calcutta. M. Planer of Erford likewise states some observations which nearly coincide with the above. From these it would appear, that between ten and two o'clock both of day and night, that is, for two hours before and two hours after the sun is on the meridian, the elevations of the barometer are less than at any other time of the day; and that between six and ten in the morning, and again between six and ten at night, their elevations and depressions are greatest. M. Chanvallon observed the same circumstance during his stay in Martinique; the mercury rises all the morning; towards mid-day it begins to decline, and continues to fall till sunset; it then becomes stationary as night approaches, previous to its rise, so that it is higher at ten at night than it was at seven or eight o'clock the preceding morning: it continues to rise till midnight, and then falls till the day breaks, when it again begins to rise as on the former days. The same fact had been observed at Surinam sixty years before. And M. Pictet of Geneva, from experiments conducted in that place, found, that the barometer stood always higher in the mornings and evenings than about mid-day. This observation is conformable to those already taken notice of, and probably depends on a similar cause.—See Mémoires de la Societé des Arts de Geneve, tom. i. 2de partie. A similar fact is taken notice of by Mr Hersburgh, in the Phil. Trans. for 1805, at an elevation of about thirteen feet within the torrid zone, the mercury being highest from about seven to nine in the morning, from noon till four P. M. it falls, being then lowest; it gradually rises again till midnight; from that time till six A. M. it falls. The diurnal variation of the barometer at sea does not correspond with those on shore, though a periodical revolution has been likewise perceived to occur in that situation. By a series of experiments, conducted by various persons in different places, and which are related by Cotte, it appears, that the tendency of the mercury to rise is greatest from a few hours after mid-day till night, when it is at its height. It is to be remarked, that the period of ascent in these instances is earlier than in those of the philosophers above mentioned. Pere Cotte found, that the difference of height at its greatest ascent, to what it is at the commencement, amounted to $\frac{4}{12}$, though in some situations the barometer stood highest a few hours past noon.

There is likewise another period when variations of the barometer are more remarkable than at any other time, which is supposed to depend on planetary influence, as these most frequently occur at the great lunar periods. It has been a general observation, that the mercury always tends to ascend during an eclipse. Pere Cotte found, that the barometer had a tendency to descend at every new and full moon, and that it inclined to rise at the quarterly periods. Toaldo found, that a greater elevation of the barometer takes place at the quarters than at the syzygies: it is less when the moon is in the northern signs than when in the southern. The mean diurnal height which corresponds to the tropic of Cancer, is less by the quarter of a line than that which corresponds to the tropic of Capricorn. The elevations are greatest when the moon is in the equinoctial points. The elevation of the barometer is greatest when the moon's apsides happen in the equinoctial points; and it is least when these occur in the solstitial signs. And there are vacillations in the mercury when the new or full moon corresponds with the apogean or perigean points. He likewise ascertained, by the industry of forty years' observation, that at the period of the moon's apogeum, the barometer rises 0.015 of an inch higher than during the perigeum: it rises 0.008 higher at the time of the quadratures than during the syzygies;

and it stands 0.022 of an inch higher at every lunation, when the moon comes nearest our zenith. Mr Howard, by examining the meteorological register of the Royal Society, says, "it appears to me quite evident, that the atmosphere is subject to a periodical change of gravity, whereby the barometer, on a mean of ten years, is depressed at least one-tenth of an inch, while the moon is passing from the quarters to the full and new; and elevated in the same proportion during the return to the quarters."—Philosophical Magazine, vol. vii. These observations have been confirmed by Cotte, from a survey of thirty-five years. It likewise has been frequently observed, that the quicksilver sinks considerably before high tides, especially at new or full moon. M. Lambert, in his essay on the Cause of Winds, likewise supports the opinion of the moon's influence over the atmosphere. He found, by the experience of ten years, that the mean height of the barometer, when the moon was in her perigean point, surpassed the mean apogean height, every time the apogeum was in the equinoctial; but when it was in the solstitial signs, it was exceeded by the apogean height. Pere Cotte has drawn up two tables, from the experiments of all those who have written upon this subject; and he finds, that the south lunistice and the perigeum are the points which have most influence in varying the gravity of the atmosphere, and that the full moon and declining equinoctial points have least influence. M. Cassan likewise perceived, that the barometer rose two-thirds of a line twice every twenty-four hours in St Domingo; and this rise always corresponded with the tides of the ocean. Similar circumstances to the above have been also taken notice of by others, as M. Mariotte, Fouchy, and De La Lande.

There are certain conditions of the atmosphere which are always accompanied by some remarkable deviation of the barometer from its mean point; these are of considerable interest, as they assist us in investigating the causes of the general range. The mercury generally stands high in serene weather, and falls previous to rain and high winds: it rises during the prevalence of an east or north-east wind, and likewise during frost: during a tempest it undergoes great oscillations, and sinks suddenly before it happens to come on. The barometer generally stands low when the air is calm, not clear, and seemingly inclined to rain: its depression is greatest when the wind is south, and during a hurricane: it is generally lower in summer and during warm weather, than in winter or in cold weather, and stands highest in both seasons during fair weather: it is, however, to be observed, that these variations depend considerably upon situation and climate. Mr Copland has found the rise of the barometer indicate a temperature greater than the monthly mean; and that the temperature is below the mean, when the barometer stands low. This observation has not been confirmed by any other person, and it has been probably influenced by some circumstances partially affecting the gravity of the air, and transitory in their operations.

Having gone over the most remarkable variations of the barometer, with the situations and times when these are most evident; the general causes by which they are produced come next to be considered. It seems probable, that the range of the barometer is not always affected by the action of a solitary cause: its variations oftenest occur, from the combined influence of several agents: but these will be comprehended more readily, when treated of under the following heads. The first, and seemingly the most general cause, is a change in the temperature of the atmosphere, either giving rise to an increase or diminution of its density. The second cause depends on the state of the air, in respect to the proportion of humidity it contains, and the state in which that humidity exists in it. In the third place, winds blowing from different points, are known to affect the range of the barometer in different ways. Electricity has been supposed to have a powerful influence over the condition of the atmosphere, and it has been therefore regarded of late years as having a considerable effect in causing variations in the range of the barometer. And under the fifth and last head, we have to investigate the lunar influence, as a cause conspiring to produce the same effect.

In entering into an examination of those causes, it will become evident, that some circumstances respecting the natural history of the atmosphere will be consequently anticipated; but we shall be careful to avoid the minute discussion of principles which have not been previously explained.

The atmosphere enjoys its temperature principally from the rays of the sun, and as its density depends in a great measure on the quantity of caloric with which it is combined, it consequently varies in this respect, according to season and latitude. The influence of the sun's rays being nearly of the same force at all times within the tropics, and the velocity of the earth's motion round its axis being greatest at the equator, the expansion of the atmosphere within these latitudes, must be nearly the same at all seasons.

The atmosphere over the line being therefore more rarefied than in any other climate, its column will on that account reach proportionally higher: its expansion must likewise diminish in receding from the tropics, the calorific rays of the sun striking the earth's surface in a direction gradually more oblique, while the centrifugal motion of the earth lessens in a similar degree; the column of air being therefore more dense, must decline in height towards the poles. For these reasons it has been imagined, that the atmosphere surrounds the earth in form of an inclined plane, sloping from the equator to the poles, where it is of the greatest density. But although there is every reason to believe, that this is the general figure of the volume of the atmosphere, it is nevertheless evident, that this form must vary according to the particular position of the earth in her orbit, and that it can only perfectly exist at the equinoxial periods. On this theory it is evident, that the permanent density of the air within the arctic circle, must be nearly as constant as the rarefied state of that within the torrid zone; it is owing to this circumstance, that the range of the barometer does not increase after passing a certain latitude, except so far as local circumstances may have an influence. The power of the causes which operate in rarefying the atmosphere within the tropics, is felt even for several degrees beyond their limits: within this space, therefore, the range of the barometer does not greatly differ from what is experienced to occur in it near to the line; but about the 38° or 40° of latitude in both hemispheres, the effects of the cold of winter begin to be more severely felt for a short time in that season; while, again, during summer, those climates are exposed to the power of an almost tropical sun; these variations of temperature, causing a considerably greater difference in the density of the air at these different seasons, the range of the barometer becomes therefore necessarily greater. In receding from the tropics, the temperature of the summer diminishes, at the same time the duration and intenseness of the cold in winter increase, till at length the endurance of winter greatly exceeds that of summer weather; therefore the range of the barometer increases till about the 50° N. lat., where the length and warmth of summer, and severity of winter, approach nearer in temperature to those seasons in the higher latitudes. In climates stretching from the 50° N. lat. towards the pole, there being therefore less difference between the condition of the air during its rarefied state in summer, and the density occasioned in it by the colds of winter, the range of the barometer does not take place to the extent it does in the former latitudes. It is in this way that we account for the variation of the barometer being greatest in latitudes intervening between that space where the temperature of the climate partakes of the temperature of the torrid zone for the greatest part of the year; and where the temperature of the climate begins to be affected more constantly by the frigidity of the boreal regions.

In northern climates, during summer, a degree of heat is frequently experienced for a short time, equal to what is felt near to the tropics; the thermometer having been known to rise in the former situation to even 70° and 80° of Fahrenheit. It is owing to the warmth of a few weeks in this season, that the range does not suffer a remarkable decrease from about the 50° N. lat. in going towards the poles. Were it otherwise, we should expect to find the range of the barometer equally limited as it is perceived to be under the equator; as the permanent density of the air must have had as great an effect in keeping the mercury at a constant height, as that of a continued state of rarefaction.

It seems likewise very probable, that the temperature of the atmosphere has a considerable influence in causing the diurnal range of the barometer. By the observations quoted above, we find, that the mercury stands lowest during that time of the day when the power of the sun's rays are greatest; though it is not improbable, that other causes may also frequently operate in bringing about these variations. These have been also imputed to the effect of planetary influence; but it is impossible to account for their regularity by this cause. The moon does not cross the meridian uniformly at one time; and from this deviation in its course, its co-operation with the attraction of the sun can have no regular effect. Nevertheless, M. Hemmar of Erfurt does not seem to think that the quicksilver of the barometer is even varied by heat: 1st, When the sun passes the meridian, the barometer, if in the act of falling, continues to fall, and the falling is accelerated. 2dly, When the sun passes the meridian, the barometer, if in the act of rising, falls or becomes stationary, or rises more slowly. 3dly, When the sun passes the meridian, the barometer which is stationary falls, if it has not risen before or after being stationary; in which case, it usually becomes stationary during the sun's passage. M. Cassan has ascertained, by experiments conducted in the island of St Domingo, that the barometer sinks only one half for every two hundred feet of elevation, in that country, of what it is found to do in the temperate climates of Europe. This circumstance is evidently owing to the great rarefaction, and the consequently increased length of the column of the atmosphere within the tropics; therefore, an elevation of two hundred feet does not cut off a portion of air in the 18° N. lat. equal in weight to the same portion in latitudes nearer to the poles; for the column over these cannot be so highly rarefied even by the heats of summer, on account of the resistance occasioned by the density of the superior strata.

Future observations may probably show, that similar experiments to those of M. Cassan will afford a variation in the fall of the barometer, at different heights in different latitudes. From what has been premised on the general effects of caloric, it will be readily understood, why the barometer stands low in warm weather, and rises while an opposite temperature prevails. A portion of air, whatever may be its temperature, can only displace another quantity equal to its own volume: thus, a column of cold dense air occupying the space previously filled with an atmosphere of an higher temperature, will cause a proportionate ascent in the barometer, by adding an increase of pressure to the atmosphere which supports it. These are the principal effects of temperature in causing variations in the barometer; but it is to be observed, that this cause acts rarely by a direct influence on the air, and that it most frequently occasions changes in the gravity of this fluid, by enabling it to retain a greater proportion of vapour. Heat is likewise a powerful agent in giving rise to winds; and in this way also, its power over the range of the barometer must be the greater. It is not the uniform temperature of climates within the tropics, but the constant blowing of the winds from one point of the compass, which M. Saussure supposes the chief cause of the steadiness of the barometer in those latitudes.

The next cause of variation in the barometer arises from the quantity of vapour contained in the atmosphere at different times. It has been observed, that the barometer sinks in serene weather, and is lowest during the prevalence of a south wind: a current of air from this point being always warmer and more rarefied, its specific gravity is consequently diminished in proportion. Caloric, besides having the power of causing the expansion of the air, has likewise the power of augmenting the evaporation of water from the earth's surface. It will be afterwards shown, that water exists in the atmosphere in the state of vapour only, a colourless fluid, which is of less specific gravity, and consequently more elastic than common air. It is in this way found, that an equal portion of vapoury air is less dense than a similar portion of air not so impregnated, though at the same temperature. The quantity of the atmospherical column being diminished, by the co-operation of the above-mentioned causes, its effects on the barometer will continue the same, while the vapour it contains retains its elasticity and temperature; but when, from any other cause, the vapour is condensed, the barometer immediately tends to rise. Vapour, in resuming the state of a liquid, is supposed to be previously condensed into an intermediate condition between its elastic and dense state: this has been called vesicular vapour by Saussure, its form being that of minute pellucid vesicles. These are of much greater specific gravity than elastic vapour, and approach in this respect nearly to that of the atmosphere. The attraction of these vesicles for each other is also greater than what exists between them and the air in which they float: they therefore gradually collect into masses or clouds. In this way, they occupy much less room than when in the more elastic state; consequently, the weight of the column of the atmosphere becomes greater. The barometer is therefore found often to rise when the air is obscured with fogs, and otherwise loaded with vesicular vapour. But when the causes of condensation are more forcible, and the vapour thereby reduced into the liquid state, as in rain, the volume of the stratum of the air being proportionally diminished by this occurrence, the density and weight of the entire atmospherical column is in this manner increased. The barometer therefore rises immediately on the commencement of rain, and sometimes previous to its fall.

The doctrine established by Leibnitz, in the Mémoires de l'Academie des Sciences for 1711, affords a farther illustration of the above-mentioned theory. That philosopher has shown, that a foreign body floating in any liquid, causes a corresponding increase of weight; but as soon as the body begins to be precipitated, the weight of the liquid is no longer affected by it. Nevertheless, the very ingenious Saussure, in his essay sur l'Hygrometrie, p. 400, &c. adduces some experiments, which tend to show that variations in the state of the barometer are rarely occasioned by the existence of water in different proportions in the atmosphere: he has calculated the specific gravity of vapour to be to that of air, at the same temperature, as 10 to 14:

and the weight of a given volume of pure air to that of the same quantity saturated with water, as 765 to 761,—a quantity which he supposes insufficient to elevate the barometer more than two lines. In confirmation of this opinion, the same ingenious philosopher quotes the observations of the Marquis Poleni respecting the effects of rain on the state of the barometer at Padua, continued during twelve years: out of 1175 instances of falls of rain, the barometer sunk only 758 times, being 645 to 1000. The observations of Van Swinden tend to confirm these experiments, he having found at Franeker in Friezland, that the predictions of rain by the barometer were as frequently deceitful as true. For these reasons, he is inclined to impute variations in this instrument, as especially owing to the effects of heat and winds, these being the most powerful and frequent causes of altering the density of air: at the same time, he does not entirely exclude the influence of vapour as tending occasionally to produce a similar effect.

It is the opinion of the ingenious Mr Dalton, "that cold alone, independent of any other circumstance, has not a tendency to increase the mean weight of the atmosphere over any place; for if it had, the mean state of the barometer would be higher in winter than in summer, contrary to experience: if, therefore, the mean state of the barometer be lower in the torrid than frigid zone, it is most probably effected by the vapoury air." But allowing that the barometer is lowest during winter in these climates, we are not to conclude against general experience, by asserting, that a low temperature has no immediate effect in rendering certain tracts of the atmosphere more dense.

The fact from which Mr Dalton seems to have inferred his opinion, can be, with greater facility, explained on principles more agreeable to general observations. In Britain, a southerly or westerly wind prevails during winter, and as the current of air from either of these points is much warmer, the weight of the column of the atmosphere is thereby diminished. No doubt the greater quantity of vapour raised in every maritime situation during winter, will likewise tend to the same effect. But Mr Dalton's own experience seems to militate considerably against the opinion above stated. He mentions, that the barometer stood higher in January 1789, than it had been for five preceding years: and this occurred during a long and uninterrupted frost, and when only 1.643 inches of rain and snow had fallen for seven weeks before; "clear proofs of the prevalence both of cold and dry air." He likewise found, that the lowest extreme was in January 1789, two weeks after the above high extreme, and "was accompanied with a strong south and south-west wind and heavy rain." Mr Dalton imputes every variation of the barometer to the quantity and condition of the vapour in the atmosphere: although this is certainly a very general cause, and its influence perhaps cannot be separated from that occasioned by temperature, there may be some instances where they operate separately, as in the observation he has himself made.

It has been observed, that winds occasion great variations in the barometer; south winds on the north side of the equator, being always followed by a sinking of the mercury, as they blow from regions where the air is warmer, more rarefied, and containing a greater proportion of vapour than the atmosphere in the latitudes over which they spread. North and north-east winds raise the barometer by an opposite effect: as they flow from regions where the heat is much less, they are of course more dense than the air over more southerly latitudes; hence arises the ascent of the barometer during the prevalence of these winds. From what has been already observed respecting the influence of the temperature of the air in causing variations of the barometer, the effect of winds in this respect will be readily understood, as they only effect similar changes in certain tracts of the atmosphere, according to their temperatures. Storms are merely to be considered as winds blowing with greater strength, their causes being similar, but operating with greater force, a more considerable portion of the atmosphere being thereby involved: storms are therefore supposed to originate in tracts of the air greatly more elevated than where winds of moderate force take their origin; and the most violent storms that occur in Europe, are almost always from a point of the compass where the atmosphere is most rarefied. It seems probable, that the sudden sinking of the barometer previous to their occurrence, will be in a proportion to the extent of the operation of these causes, and the distance at which they act from the point of observation: the oscillations of the mercury will therefore be frequently perceived long before the effects of the storm are experienced below.

These elementary commotions have of late years been ascribed to the sudden destruction of a portion of the atmosphere itself within the polar circles: the contiguous air, rushing in with violence to fill up the vacuum, has been supposed to give origin to all these appearances. This hypothesis was perhaps originally suggested by the late ingenious Dr Darwin, but there has not been even a solitary instance of its probability brought forward to establish the opinion, by any of those who have embraced it; nor does it appear consistent with the economy of nature, that such an occurrence should ever happen; neither does there seem to be any cause sufficiently powerful to annihilate suddenly a portion of the atmosphere, so as to occasion a commotion in it equal to produce the storms so frequently experienced. The changes which the atmosphere undergoes in the general economy, are slow and uniform ; and such is the care of Providence in preserving the properties of this fluid, that its principles, which occasionally disappear, are again supplied by processes equally general and permanent.

Beccaria, in his Letters on Electricity, supposes, that the electric fluid abounding in the air occasions some alteration in its density : he perceived the mercurial column to descend on the occurrence of a flash of lightning; still he does not suppose that its effects in this way can be either great or permanent. Indeed so little is known of the power of electricity upon the air, that nothing certain can be advanced on the subject. However, M. Manduyt, in the Mémoires de la Société Royale de Médicine, for 1776, observes, that the barometer frequently ascends, as the electricity of the air becomes weaker, and that it falls in like manner when its electric state becomes stronger; upon the whole, he does not think that the electricity of the air has an immediate effect, either in the barometer or thermometer.

The supposed influence of the moon over the atmosphere, is an opinion handed down to us from the earliest antiquity: it has been found agreeable to common observation in every age and country; yet the peculiar agency of that planet, in occasioning changes on the state of the atmosphere, is not yet accurately determined, though the subject has been carefully investigated by men of great talents and ingenuity. When treating of the properties of heat, we had occasion to relate some experiments which evidently prove that the effect of the moon upon the atmosphere does not arise from the communication of caloric, as the slightest rise of temperature could not be perceived when its concentrated rays were thrown upon the bulb of a delicate thermometer. The general opinion that is now entertained, of the moon's influence in causing variations in the density of the atmosphere, is that of gravitation, supposing that it acts in a manner similar to the power it exerts in causing tides in the ocean. This theory is strenuously supported by Toaldo and the celebrated Lambert. There are many circumstances which incline us to believe in the correctness of this opinion, although its influence over the air is apparently less, on account of the less density of this medium; but from the experiments already related, there cannot remain a doubt, that accumulations, or tides, in certain portions of the atmosphere, do take place, corresponding to particular lunar points: probably daily accumulations occur in the atmosphere, but, owing to its great tenuity, and our position on the earth's surface, it is impossible to render such evident. In the more distant periodical variations of the atmosphere, it agrees with the tides of the ocean: the tides of the latter are greatest twice every month: they are likewise increased at four different periods of the year, at the equinoxes, and solstices; and at all these periods the atmospherical accumulations are seemingly increased: in this way, the tides of both so far correspond. This influence of the sol lunar attraction over the atmosphere, must be likewise most remarkable within the tropics: this having been also supposed to operate in giving a permanency to the current of the trade winds.

The late ingenious Professor Robison has remarked, that were there a tide in the atmosphere, it must necessarily take a westerly direction, on account of the corresponding westerly current in the tides of the ocean, and that the increase of the tides of the atmosphere would be 120 feet, were its height equal to the radius of the earth; but he does not admit, that the height of the atmosphere is so great as to give rise to so high tides: indeed, he says, "they cannot sensibly exceed those of the ocean, and this cannot change the height of the mercury in the barometer $\frac{1}{100}$ of an inch." However, the facts we have already mentioned, afford us good reason to presume, that periodical accumulations do take place; and even the small degree of variation in the barometer, as allowed by Dr Robison to be possible, is quite sufficient to mark this circumstance.

The Abbé Mann, as well as some other ingenious men, suppose, that the united effects of the attraction of the sun and moon must elevate the earth's atmosphere, and extend it in the inverse ratio of the square of the distance, so as to make it take the form of an oblong spheriod, the greater diameter of which will always follow the sphere of attraction.

It has been always observed, that changes in the weather bear some reference to the great lunar periods; and the influence of the moon has been thought to have a considerable effect on living animals. Physicians have frequently attributed to the lunar power, the aggravation of, and even the cause of diseases,—an opinion which is rendered probable, in a certain degree, from late observation in different parts of the world. Aristotle observes, that the coldest and driest weather occurs during the first fifteen days of the moon,—an opinion which is confirmed by Macquer, who likewise found, that thaws and warm weather happen more frequently in the latter fifteen days. Winds are observed to be highest about the time of an eclipse, and about the equinoxes: at Hudson's Bay, it is observed, that the cold becomes more intense a few days before new and full moon: it may be finally remarked, that the continual variation of the atmosphere, in point of density and elasticity, from a variety of causes,—its excessive tenuity and facility of motion, and probably the influence of electricity in altering its condition,—may long baffle the efforts of philosophers, in their attempts to decide this question with precision.

Before we dismiss the investigation of the causes of variations in the barometer, it is necessary to attend to those circumstance which produce a difference in the range of the barometer in corresponding latitudes in Europe, and of Asia and America. The ingenious Dr Kirwan supposes, that this density is occasioned by a quantity of air continually ascending within the torrid zone, which, at a certain degree of elevation, takes a direction towards the poles, in consequence of the declivity of the plane of the atmosphere; and as it occasionally lingers over the high grounds of Asia and America, it necessarily increases the weight of the column below, and thereby raises the mercury in the barometer. This opinion is extremely plausible, and has therefore been generally embraced; but the accuracy of the explanation still appears very doubtful. That there is a circulation of the atmosphere from the poles to the line, and in the opposite direction, will not be questioned, even by the most superficial observer; but, as we proceed in this investigation, it will be found, that the circulation of the air in the manner imagined by Dr Kirwan, can only take place in a very partial degree, and is by no means equal to produce the effects he ascribes to it. It may be remarked in this place, that the very rarefied state of the atmosphere in the upper regions of the air over the torrid zone, in consequence of the diminution of pressure, must effectually prevent any extensive circulation of it in this way. The medium temperature of the climate all along the western coast of North America, is also less than in the same latitudes in Europe; the changes, likewise, from heat to cold are more sudden; and having commenced, the temperature is more permanent. It seems therefore to be owing to the rapid succession of different temperatures, that the fluctuations of the barometer are there observed to be greater; and to the continuation of a more intense degree of cold during winter, that the barometer stands higher in those latitudes during that season. In the same manner, an immediate succession of a hot vapoury air in spring and summer, induces a corresponding low state of the thermometer through these seasons. This opinion seems to receive some proof, by the facts contained in the following table, taken from Volney's View of the Climate of America.

	Latitude.	Maximum of cold.	Maximum of heat.	Scale of variation.
Rome,	41° 53′	0	24	24
Marseilles,	43° 17′	4	25	29
Padua,	45° 22′	10	29	39
Salem, in America,	42° 35′	19½	31½	51

It has been shown, that the mean weight of the atmosphere is nearly the same in every latitude on a level with the ocean, though it is not of an equal height in every climate; as the altitude of the atmosphere in every country must vary according to the elevation of the land above the sea-shore. Its column being shorter on the tops of mountains, there follows a corresponding diminution in the range of the barometer. This seems to be likewise owing to the greater uniformity of temperature of the air over such situations in all seasons. In hilly countries, however, the range of the barometer in the low grounds is always greater than in places that are level, and not interrupted with mountainous tracts: in the former situations, the density of the atmosphere is liable to be suddenly altered by the volume of cold air descending occasionally from the high grounds; while, at other times, the atmosphere over the valleys becomes frequently more rarefied, by the greater reflection of the sun's rays from the sides of the mountains.

When we come to treat of the temperature of the atmosphere, we shall have occasion to mention several circumstances, which conspire to render the eastern coast of Asia much colder in winter, than parallel latitudes upon the western shores of Europe. In this way, the height of the barometer is much greater during that season, in consequence of the greater density of the atmosphere. In summer, again, from the immense extent of land, and prevalence of westerly winds, the heat of these climates is probably greater than those of Europe, and, of course, the range of the barometer must be proportionally greater.

It has been observed, that the highest state of the barometer takes place in our climates during winter. This does not appear to be entirely occasioned by the denser state of the atmosphere at that season; it is probably in a great measure owing to an accumulation of the atmosphere over our hemisphere, which is then most inclined. For, even admitting that the atmosphere surrounds the earth, in form of two declined planes; in consequence of its specific gravity, and its extreme susceptibility of motion, this particular figure must vary according to the sun's position in the ecliptic. It is owing to this circumstance alone, that the quantity of our atmosphere is actually greater during winter; consequently, the range of the barometer should be greater in that season, and its mean height should be likewise higher. Again, during our summer the air is accumulated over the southern hemisphere, which, by diminishing the quantity of the atmosphere over the northern division of the globe, lessens the range of the barometer, and causes its mean point to stand lower than it otherwise would do.

SECT. III.

OF THE TEMPERATURE OF THE ATMOSPHERE, AND OF THE CAUSES OF VARIETIES OF CLIMATE, &c.

An opinion seems to have prevailed in early times, that the heat of the atmosphere is greatest in its superior regions, and that it is more humid and cold the nearer to the earth's surface. This idea even continued in a considerable degree till the days of Mr Boyle, and was probably first suggested by perceiving the temperature of the air always corresponding to the sun's position in the ecliptic; an observation which would naturally lead many into this opinion, as it was made at an æra when the knowledge of the properties of the air, and of the influence of the solar rays, were too limited to enable them to form an accurate idea of the manner of their operation. Yet actual observation has confirmed the reverse of this statement; and there is no fact better ascertained, than that the temperature of the atmosphere decreases in proportion to its elevation above the earth's surface. The sun's rays are the principal source from whence the air is supplied with heat, though it is admitted, that the influence of the changes in the condition of the vapours that are frequently found mixed with it, may add occasionally to the same effect. But it is an investigation into the influence of the former cause, that falls especially to be considered here. The rays of the sun, in passing through a transparent body, do not impart heat to it, otherwise they would communicate a portion of caloric to the atmosphere, as soon as they begin to penetrate that medium. It was therefore considered as a very interesting subject of investigation, during a considerable period of last century, in order to ascertain in what particular manner the atmosphere acquires its temperature; and it is now generally agreed, that the sun communicates warmth to this medium, in consequence of the reflexion of his rays from the earth's surface.

Lord Verulam has anticipated M. Bouguer in the merit of this discovery, which satisfactorily explains the cause of the higher temperature of the lower strata of the air, and why the heat decreases in proportion as we ascend in it. The lower stratum acquires its temperature, not only by having the sun's heat communicated to it in the form of reflected rays, but likewise by remaining in contact with the earth, which is a good conductor of heat, and must therefore be generally in a state giving off this fluid: but as the air is a bad conductor of the matter of heat, it is but slowly propagated through its superior regions; it is therefore generally supposed, that the atmosphere communicates heat through its different strata, in consequence of its power of carrying this fluid. Were the atmosphere a good conductor of caloric, it must have speedily acquired a very high degree of temperature through its whole extent, as the matter of heat must have accumulated much faster, than it could be imparted to other bodies: it would thereby have rendered the earth uninhabitable. The temperature of the atmosphere is found to diminish so remarkably as we ascend in it, that on arriving at a certain elevation in every latitude, a degree of cold is experienced always below the freezing point. This has been called by Dr Kirwan the term of perpetual congelation; but although this temperature prevails at certain heights in every climate under the equator, as well as within the arctic circle, it is to be observed, that this term does not occur at an equal height in every latitude: it not only differs according to latitude, but it varies likewise in the different seasons of the year in every climate distant from the equator. In

...Above by ...lcula...	Diffe-rence.	Authors.
	..75	Bouguer.
		Saussure's voy-...ges, p. 941.
		...ckburgh, Ph. ...777, p. 530. ...urgh.

the ... of conge... ...ude 28° being ... this and 32° is 40... 40° 3 : 12072. In this way he ...e following table.

...BLE *of the Lower and Upper Term of Congelation.*

Latitude.	Mean Height of the Lower Term of Congelation.	Mean Height of the Upper Term of Congelation.
0	15,577	28,000
5	15,457	27,784
10	15,067	27,084
15	14,498	26,061
20	13,719	24,661
25	13,030	23,423
30	11,592	20,838
35	10,664	19,169
40	9,016	16,207
45	7,658	13,730
50	6,260	11,253
55	4,912	8,830
60	3,684	6,546
65	2,516	4,676
70	1,557	2,809
75	748	1,346
80	120	207

consequence of the permanence and intenseness of the heat which prevails near the line, the term of congelation is greatly more elevated there than in any other latitude; and it is found lower in the atmosphere, as we approach either pole, where, for the greatest part of the year, it is nearly equal with the earth's surface.

Bouguer found, that it begins to freeze on ascending Pinchinca to the height of 15,577 feet. Saussure perceived the temperature of the air to be at the freezing term, when he had ascended the Alps to the height of 13,428 feet. At Auvergne in France, the freezing point is found at somewhat more than 7000 feet above the earth's surface. In Britain, during summer, it is from about 5000 to 6000 feet above the surface; and it is owing to the lowness of that point in the atmosphere, that snows are frequently seen to remain on the tops of our highest mountains during summer: it is in consequence of the declining temperature of the air according to the ascent, that temperate climates are found under the line, in every respect possessing all the advantages of those without the tropics.

The following table from Dr Kirwan's ingenious treatise on the Temperature of Climates, shews at one view the height of the term of congelation in different latitudes: it is the result of a calculation founded on the most correct observations, and is therefore presumed to be as accurate as the nature of the investigation will admit. He first ascertained the mean annual heat of any latitude, and then calculated the difference between it and the freezing point. In this way, the mean heat of the equator being found to be 84°, the difference between it and 32°, the point of congelation, is 52°; the mean heat of latitude 28° being 72° 3, the difference between this and 32° is 40° 3; then, 52° : 15577 :: 40° 3 : 12072. In this way he drew up the following table.

TABLE *of the Lower and Upper Term of Congelation.*

Latitude.	Mean Height of the Lower Term of Congelation.	Mean Height of the Upper Term of Congelation.
0	15,577	28,000
5	15,457	27,784
10	15,067	27,084
15	14,498	26,061
20	13,719	24,661
25	13,030	23,423
30	11,592	20,838
35	10,664	19,169
40	9,016	16,207
45	7,658	13,730
50	6,260	11,253
55	4,912	8,830
60	3,684	6,546
65	2,516	4,676
70	1,557	2,809
75	748	1,346
80	120	207

But, in ascending above the ordinary term of congelation, we arrive at a point in the atmosphere, where it is still colder, and to this point no vapour ever rises. Bouguer calls this the upper term of congelation. The first, or lower term, must vary in height according to the season of the year, &c.; but this superior point is supposed to be at all times stationary, both in situation and temperature. From the manner in which the atmosphere receives its heat, and the very small power it has of conducting that fluid, there can be no doubt, that the higher regions are cooled down to the lowest possible degree. Every calculation respecting the height where this permanent term of congelation takes place, must therefore be rather considered as a matter of curiosity, as the circumstances depending on the variations of the temperature of climates, are sufficiently ascertained by having determined the height at which the lower term of congelation commences. This greater degree of cold in the higher regions of the air, answers the most beneficial purposes, by retaining it in a necessary state of density, which otherwise must have diminished it in too great a degree, from the diminution of pressure. The following table, taken from Dr Kirwan's Essay on the Atmosphere, in the 8th volume of the Irish Transactions, shews at one view the heats observed and calculated in different places, and at different heights.

Latitude.	Heights.	Heat. Below.	Heat. Above by observation.	Heat. Above by calculation.	Difference.	Authors.
0°	Pinchinca, 15564.	83°.7	29.75	30.5	0.75	Bouguer.
38	Etna, 10954.	73.25	40.8	47.2	6.4	Saussure's voyages, p. 941.
46	Salene, 2831.	73	64	64.16	16	Shuckburgh, Ph. Tr. 1777, p. 530.
46	Mole, 4211.	63.9	56	53.7	2.3	Shuckburgh.
46	Col de Geant, 11273.	81	41.5	42.5	1	Saussure.
46	Mont Blanc, 14624.	82.8	26.82	26.44	0.38	Saussure, 2000.
53	Snowden, 3555.	60	47.75	47.1	0.65	Roy, Phil. Trans. 1777, p. 779.
53	Moel Eleo, 2371.	62.5	51	51.3	0.3	Roy, ibid.
56	Arthur's Seat, near Edin. 803.	54	50.5	50	5	Roy, ibid.
56	Kirk Yelton Cairn, 1544.	54.5	47.25	48.3	1.05	Roy, ibid.
56.30	Shehallion, 3281.	56	45	41.4	3.6	Roy, ibid.
56.30	Rolfrach, 1076.	60	56.75	54.5	2.25	Roy, ibid.
56.30	Knockfaile, 1364.	54	48.5	48.5	0	Roy, ibid.
56.30	Glenmore, 1279.	55	51.5	49.6	1.9	Roy, ibid.
56	Tinto, 1642.	58	51	50.3	0.7	Roy, ibid.
46	Dole, 4810.	78.25	65	63.46	1.5	Roy, ibid.
51.31	Kew Pagoda, 116.	49.25	49.25	49.05	0.2	Roy, ibid.
80	Hackluyt Hill. 1503.	50	42	43	1	Phipp's voyages.

The variation of the thermometer in different latitudes, appears at first sight the only proper method of ascertaining the mean temperature of different climates; and this continued to be the only method till about the middle of last century, when, to obviate the tediousness and uncertainty attending continued observations throughout the year, M. Mayer of Stockholm attempted it by means of a calculation from facts previously acquired. He found, that the decrease of temperature from the equator to the poles, takes place in arithmetical progression; that therefore the annual temperature of any latitude is an arithmetical mean between the mean of the annual temperature of the equator and the pole: but Dr Kirwan has improved the way of making the equation, and he proceeds on the following principles to reduce the mean annual temperature of every latitude. Supposing the mean annual heat to be greatest under the equator, and least under the poles, then if the temperature of the equator be m, and the temperature of the poles $m-n$, and putting ϕ for every other latitude, the temperature of that latitude will be $m - n \times \sin \varphi$. It must likewise be remarked, that the following table was calculated by assuming the Atlantic Ocean for a standard; it will therefore more nearly correspond with the temperature of the air over maritime places. He preferred that part of the ocean which stretches between the 80th of

North, and 45th degree of South latitude, where it is widest, and least interrupted with land: it there covers a considerable portion of the globe, and consequently its temperature is more permanent. However, there is still a more simple way of ascertaining the mean temperature of latitudes: this is obtained by measuring the heat of springs of water. The heat of the earth at a certain depth is known to be constant, neither increasing during the heats of summer, nor diminishing by the cold of winter. This temperature has been found to be always the mean of that of the latitude of the place; therefore water, filtrating slowly through this medium, must acquire the same degree of heat. From this circumstance, it is explained why springs never freeze, even during the most intense frosts, but are then found warmer than the air, and are therefore very frequently observed in that season covered with vapour. Again, during the opposite season, the same sources of water feel proportionally more cool, and have their temperature much lower than that of the surrounding air.

TABLE *of the Mean Annual Temperature of the Standard Situation, in every Latitude.*

Lat.	Temper.	Lat.	Temper.	Lat.	Temper.
90	31,	61	43,5	32	69,1
89	31,04	60	44,3	31	69,9
88	31,10	59	45,09	30	70,7
87	31,14	58	45,8	29	71,5
86	31,2	57	46,7	28	72,3
85	31,4	56	47,5	27	72,8
84	31,5	55	48,4	26	73,8
83	31,7	54	49,2	25	74,5
82	32,	53	50,2	24	75,4
81	32,2	52	51,1	23	75,9
80	32,6	51	52,4	22	76,5
79	32,9	50	52,9	21	77,2
78	33,2	49	53,8	20	77,8
77	33,7	48	54,7	19	78,3
76	34,1	47	55,6	18	78,9
75	34,5	46	56,4	17	79,4
74	35,	45	57,5	16	79,9
73	35,5	44	58,4	15	80,4
72	36,	43	59,4	14	80,8
71	36,6	42	60,3	13	81,3
70	37,2	41	61,2	12	81,7
69	37,8	40	62,	11	82,
68	38,4	39	63,	10	82,3
67	39,1	38	63,9	9	82,7
66	39,7	37	64,8	8	82,9
65	40,4	36	65,7	7	83,2
64	41,2	35	66,6	6	83,4
63	41,9	34	67,4	5	83,6
62	42,7	33	68,3	0	84,

By the same standard by which the above table is formed, Mr Kirwan has likewise calculated the mean monthly temperature of every latitude, for every month of the year: and having ascertained by actual observation, that the mean heat of April approaches nearly to the mean temperature of the year; and considering, that the temperature of the atmosphere is chiefly owing to the force of the sun's rays, this will therefore depend in a great degree on his position in the ecliptic, in every latitude receding from the equator. The mean heat of April being found, and the sun's altitude being taken, the mean heat of May and the other months are ascertained thus: The sine of the mean altitude of the sun being to the mean heat of April, in the same degree as its altitude in any other month, must be to the mean heat of it. But it is to be observed, that this calculation would make the mean heat of the months subsequent to August at too low a temperature, as it cannot include the other sources of heat, which, in that season of the year, bear a considerable proportion to that which is derived from the sun's rays; the mean temperature of these months is therefore calculated on the supposition of its being an arithmetical mean between the solar and terrestrial heats.

TABLE *of the Monthly Mean Temperature of the Standard, from Lat.* 80° *to Lat.* 10°.

Lat.	80°	79°	78°	77°	76°	75°	74°	73°	72°	71°	70°	69°	68°	67°	66°	65°	64°	63°
Jan.	22	22.5	23	23.5	24	24.5	25	25.5	26	26.5	27	27.5	27.5	28	28	28	29	30
Feb.	23	23	23.5	24	24.5	25	25.5	26	26.5	27	27.5	28	28	28.5	29	30	31	32
March	27	27.5	28	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33	33.5	34	35	36	37
April	32.6	32.9	33.2	33.7	34.1	34.5	35	35.5	36	36.6	37.2	37.8	38.4	39.1	39.7	40.4	41.2	41.9
May	36.5	36.5	37	37.5	38	38.5	39	39.5	40	40.5	41	41.5	42	42.5	43	44	45	46
June	51	51	51.5	52	52	52	52.5	53	53.5	54	54	54.5	54.5	54.5	55	55	55.5	55.5
July	50	50	50.5	51	51	51	51.5	52	52.5	53	53.5	53.5	53.5	54	54.5	54.5	55	55
August	39.5	40	41	41.5	42	42.5	43	43.5	44	44.5	45	45.5	46	47	48	48.5	49	50
Sept.	33.5	34	34.5	35	35.5	36	36.5	37	38	38.5	39	39.5	40	41	42	43	44	45
Oct.	28.5	29	29.5	30	30.5	31	31.5	32	32.5	33	33.5	34	34	35	36	37	37.5	38
Nov.	23	23.5	24	24.5	25	25.5	26	26.5	27	27.5	28	28.5	29	30	31	32	32.5	33
Dec.	22.5	23	23.5	24	24.5	25	25.5	26	26.5	27	27.5	28	28	29	30	30.5	31	31

TABLE *of the Monthly Mean Temperature, &c. continued.*

Lat.	62°	61°	60°	59°	58°	57°	56°	55°	54°	53°	52°	51°	50°	49°	48°	47°	46°	45
Jan.	31	32	33	34	35	36	37	38	39	40	41	42	42.5	42.5	43	43.5	44	44.5
Feb.	33	34	35	36	37	38	39	40	41	42	43	44	44.5	44.5	45	45.5	46	46.5
March	38	39	40	41	42	43	44	45	46	48	49	50	50.5	51	52.5	53	53.5	54.5
April	42.7	43.5	44.3	45.09	45.8	46.7	47.5	48.4	49.2	50.2	51.1	52.4	52.9	53.8	54.7	55.6	56.4	57.5
May	47	48	49	50	51	52	53	54	55	56	57	58	58.5	59	60	61	62	63
June	56	56	56	56.5	57	57	57.5	58	58.5	59	59	60	61	62	63	64	65	66
July	55.5	55.5	56	56.5	57	57.5	58	59	60	61	62	63	63.5	64	65	66	67	68
August	51	52	53	54	55	56	57	58	59	60	61	62	63.5	64	65	66	67	68
Sept.	46	47	48	49	50	51	52	53	54	55	56	57	58.5	59	60	61	62	63
Oct.	39	40	41	42	43	44	45	46	47	48	49	50	50.5	51	52	53	54	55
Nov.	34	35	36	37	38	39	40	41	42	44	44.5	46	46.5	47	48	49	50	51
Dec.	32	33	34	35	36	37	38	39	40	41	42	44	44.5	45	46	47	48	49

TABLE *of the Monthly Mean Temperature, &c. continued.*

Lat.	44°	43°	42°	41°	40°	39°	38°	37°	36°	35°	34°	33°	32°	31°	30°	29°	28°	27°
Jan.	45	45.5	46	46.5	49.5	51	52	53.5	55	56.5	59.5	63	63	63	63.5	63.5	63.5	64
Feb.	47	48	49	50	53	56.5	58	60	61	62	63	64.5	66	67	68.5	68.5	69.5	69.5
March	55.5	56.5	58.5	59.5	60	60.5	61	62	63	64	65	66.5	67.5	68.5	69.5	71	72	72.5
April	58.4	59.4	60.3	61.2	62.1	63	63.9	64.8	65.7	66.6	67.4	68.3	69.1	69.9	70.7	71.5	72.3	72.8
May	64	65	66	67	68	69	70	70.5	71	71.5	72	72.5	73	73	73.5	74.5	75.5	76
June	67	68	69	70	70.5	71	71	71	71.5	71.5	72	72.5	73	73	73.5	74.5	75.5	76
July	69	69.5	70	70	71	71	72	72	72.5	72.5	72.5	72.5	73	73	73.5	74.5	75.5	76
August	69	69.5	70	70	71	71	72	72	72.5	72.5	72.5	72.5	73	73	73.5	74.5	75.5	76
Sept.	64	66	68	69.5	70.5	71	71.5	72	72.5	72.5	72.5	72.5	73	73	73.5	74	75.5	76
Oct.	56	57	58	59	60	61	62	63	64	65	66	67.5	68.5	69.5	70.5	71	72.5	72.5
Nov.	52	53	54	55	56	57	58	59	60	61	62	63	64.5	65.5	66.5	68	69	69.5
Dec.	50	51	52	53	54	55	56	57	58	59	60	61	62.5	63.5	64.5	66	67	67.5

TABLE *of the Monthly Mean Temperature, &c. continued.*

Lat.	26°	25°	24°	23°	22°	21°	20°	19°	18°	17°	16°	15°	14°	13°	12°	11°	10°
Jan.	64.5	65.5	67	68	69	71	72	72.5	73	73.5	74	74.5	75	76	76.5	77	77.5
Feb.	70.5	71	72	72	72.5	74	75	76	76.5	77	77.5	78	78.5	79	79.5	79.8	80
Mar.	73	73.5	74.5	75	75.5	76	77	77.5	78	78.5	79	79.5	80	80.8	81	81.5	81.8
Apr.	73.8	74.5	75.4	75.9	76.5	77.2	77.8	78.3	78.9	79.4	79.9	80.4	80.8	81.3	81.7	82	82.3
May	76.5	77.5	78	78.5	79.5	80	80.5	81	81.5	82	82.5	83	83	83.5	84	84	84.3
June	76.5	78	78.5	79	79.5	80	80.5	81.5	82	82.5	83	83.5	83.8	84	84.3	84.6	84.8
July	76.5	78	78.5	79	79.5	80	80 5	81.5	82	82.5	83	83.5	83.8	84	84.3	84.6	84.8
August	76.5	78	78.5	79	79.5	80	80.5	81.5	82	82.5	83	83.5	83.8	84	84.3	84.6	84.8
Sept.	76.5	77.5	78	78.5	79	79.5	80	81	81.5	82	82.5	83	83	83.5	84	84.3	84.6
Oct.	73	73.5	74.5	75	75.5	77	78	79	80	81	81.5	82	82.5	83	83.5	83.8	84
Nov.	71.5	72	73.5	74	74.5	75	75.5	76	77	78	78.5	79	79.5	80	80.5	80.8	81
Dec.	68.5	69.5	70.5	71	71.5	72	72.5	73	74	75	75.5	76	76.5	77	77.5	78	78.5

From experiments performed by Mr Macgowan, in the vicinity of Edinburgh, he has shewn, that the coldest month there is January; and we see by Dr Kirwan's tables, that this is the coldest month in every latitude: in the same way, we likewise find, that June is the warmest month in all places above 60 degrees of latitude; but from that, in proceeding to the equator, July and August enjoy the highest temperature. These circumstances can be very easily accounted for, on the principles which regulate the earth's motion. At the summer solstice, the sun's power is greatest in the latitudes beyond the 60th degree; but in the latitudes below this degree, they continue to receive heat from this source for some time during his decline in the ecliptic, which, co-operating with the heat acquired by the earth during his ascent, tends to increase the temperature of the air; which is therefore found to be highest a few weeks after he has passed the solstitial signs. On the other hand, the latitudes within 48° are never so much cooled, owing to the more direct impression of the sun's rays, and their power being greatest at the solstices; consequently, the temperature of these latitudes will be greatest at that period. Within about 10 degrees of the equator, the temperature varies but little; and an uniform degree of temperature prevails likewise in the 10 degrees nearest the poles; yet even in the space included within these latitudes, the difference between the coldest and hottest months, as well as the mean temperature of different years, varies in proportion to the distance from the equator.

The difference of temperature that frequently occurs in places lying under the same parallel, has been supposed by Dr Kirwan to be chiefly owing to a difference of elevation; and, according to his opinion, if the elevation be only at the rate of 6 feet *per* mile from the sea-shore, then we must allow one-fourth of a degree for every 200 feet of elevation, being the proportion of diminution of the mean temperature of the place.

If the elevation be 7 feet *per* mile, allow $\frac{1}{3}$ of a degree,

13 feet, $\frac{4}{10}$

15 feet or more, $\frac{1}{12}$

This elevation may be readily ascertained by means of the barometer, by observing its mean height, and deducting it from the elevation of the mercury on a level with the ocean; the difference, calculated on the principles laid down in the table of Sir George Shuckburgh, will afford the necessary result. Dr Kirwan likewise supposes, that the greater any place is distant from the standard ocean, its temperature will vary in a corresponding degree; and he has found by calculation, that the mean temperature for the year is depressed or raised for every 50 miles at the following rate: From lat. 70° to lat. 35 cooled $\frac{1}{3}$ of a degree.

35		$\frac{1}{8}$
30		0
25	warmed	$\frac{1}{5}$
20		$\frac{1}{2}$
10		1°

When the elevation is less than 6 feet *per* mile, Dr Kirwan thinks its effects are so blended with those of distance from the standard ocean, that the diminution for the allowance of temperature is to be made for both: it therefore appears from the last table, that from lat. 70 to lat. 30, elevation and distance conspire in producing the same effect, a diminution of temperature. But in latitudes between 30°, this ingenious philosopher supposes that elevation and distance from the standard ocean, in general counteract each other, and therefore the effect of one is to be subtracted from that of the other.

That the thermometer descends in proportion as we ascend in the atmosphere, is established by what has been already said respecting the manner how the air acquires its temperature; but from many circumstances connected with the properties of the air itself, the rate of its variation must be difficult to determine. Saussure, in several journeys over the Alps, found, that the diminution of temperature amounts to 1° for every 287 feet. Dr Thomas Heberden found, that in ascending the Azores, the thermometer sunk 1° for every 145 feet; and that in Porto Rico, whose height is 5141 feet, the thermometer fell 1° for every 90 feet of elevation. A thermometer placed on the top of Arthur's Seat, near Edinburgh, stood 3° lower than another kept in a situation on a level with its base.

M. Bouguer also perceived his thermometer to stand at 30°, when 15,564 feet above the level of the sea, on the summit of the Andes; while another placed at the base of the mountain, stood at 84°. It is to be observed, that as the temperature of the atmosphere is continually varying from within a few degrees of the equator, the season of the year, previous state of the weather, &c. will therefore cause a discordance in these experiments, when performed at different periods, even in the same situation.

The variations of the thermometer have likewise been called its range, and it includes the space in which it varies, either in rising above, or in sinking below its mean temperature: this variation increases, in receding from the equator, nearly in a similar manner to what is observed of the range of the barometer. The temperature of islands is never so cold during winter, as that of the adjacent continent; and in summer, the heat of the air never ascends so high: but the variation of the thermometer in islands differs according to their extent, and distance from the main land. Thus, the cold of the northern part of Britain, rarely falls so low in winter as is frequently experienced in its southern division; neither does the heat of summer rise so high. The atmosphere is rarely cooled down in any part of the island to zero of Fahrenheit, though this occurrence is frequent in parallel latitudes on the continent; and it oftener occurs in the south of Britain, than in any other part of the island. The late Dr Walker observed the thermometer to stand at two degrees below zero, in Tweeddale, on one of the first days of January 1768, at eleven o'clock at night. Mr Macgowan takes notice of a similar low temperature having occurred in February 1772: in both instances, trees were suddenly rent, and eggs were frozen by its severity. The highest degree of heat that was perhaps ever remarked in the northern division of the island, was observed at Moffat on the 20th August 1764, at 10 o'clock, A. M. The thermometer then rose in the sun's rays to 116°: on the 14th July same year, it stood in the same situation at 84°; and Dr Walker, from long observation, supposes the medium of our greatest summer heats to be about 70°, which is greater than the calculation in Mr Kirwan's table. By experiment, a degree of heat was experienced in the open air at Lancaster in 1757, that raised the thermometer to 140°; but this was in a great measure owing to the reflection of the sun's rays from a white-washed wall. It is in this manner that the air can be heated in Egypt, and other warm countries, to a much higher degree than the natural temperature of the climate. According to Dr Kirwan, the temperature of different years differs very little near the equator; but this difference increases in latitudes as they approach the poles. Between latitudes 35 and 60, in places adjacent to the seas, it generally thaws when the sun's altitude is 40°, and seldom begins to freeze until the sun's meridian altitude is below 40°. It rarely freezes in latitudes within 35° of the line, unless in very elevated situations. In the southern provinces of North America, the thermometer frequently continues during summer from 85° to 90°, and it even sometimes exceeds 100°. An equal degree of temperature is frequently experienced in the atmosphere over the coast of Peru, Africa, and the East Indies; and it even rises greatly higher in the interior of those countries. In Siberia, during summer, the temperature of the air has been known to rise so high as 70° for a short time; and, in like manner, it has been experienced at 82° in Petersburgh: but in the higher latitudes towards the poles, the cold of the air is much more intense in the winter. In the vicinity of the arctic circle, the thermometer has been known to sink to 70° below zero, and the quicksilver in the tube of the instrument to be frozen. This occurrence happened to Professor Pallas; and a similar effect was occasioned to Maupertius, in lat. 65° 30′, when the spirit of wine in his thermometer was converted into a column of ice. It has been said, that the cold of Siberia was so very severe in winter 1779, as to cause the thermometer descend so low as 99°, 107°, and even 113° below zero; but from what has been mentioned of the congealing of the mercury at a much higher temperature, every measurement below the degree of 40° below 0° must be very uncertain; for besides the change which the quicksilver is thus liable to undergo at low degrees of temperature, it has been observed to sink suddenly after passing a certain degree, and in this way to indicate several degrees at once.

The following table gives a view of the mean annual temperature of places differently situated, and taken by actual admeasurement, copied from Dr Kirwan's estimate of the Temperature of Climates.

	North Lat.	Longitude.	Mean Annual Heat.
Wadso, in Lapland,	70° 5′		36°
Abo - -	60 27	22° 18′ E.	40
Petersburgh, - -	59 56	30 24 E.	38 8
Upsal, - - -	59 51	17 47 E.	41 88
Stockholm, - -	59 20	18 E.	42 39
Solyskamski, - -	59	54 E.	36 2
Edinburgh, - -	55 57	3 W.	47 7
Franeker, - -	53	5 42 E.	52 6

	North Lat.	Longitude.	Mean Annual Heat.
Berlin, - - -	52°32′	13° 31′ E.	49°
Lyndon, in Rutland, -	52 30	0 3 W.	48 03
Leyden, - - -	52 10	4 32 E.	52 25
London, - - -	51 31		51 9
Dunkirk, - - -	51 02	2 7 E.	54 9
Manheim, - -	49 27	9 2 E.	51 5
Rouen, - - -	49 26	1 W.	51
Ratisbon, - -	48 56	12 05 E.	49 35
Paris, - - -	48 50	2 25 E.	52
Troyes, in Champaigne,	48 18	4 10 E.	53 17
Vienna, - - -	48 12	16 22 E.	51 53
Dijon, - - -	47 19	4 57 E.	52 8
Nantes, - - -	47 13	1 28 E.	55 53
Poitiers, - - -	46 39	0 30 E.	53 8
Lausanne, - -	46 31	6 50 E.	48 87
Padua, - - -	45 23	12 E.	52 2
Rhodez, in Guienne, -	45 21	2 39 E.	52 9
Bourdeaux, - -	44 50	0 36 W.	57 6
Montpelier, - -	43 36	3 73 E.	60 87
Marseilles, - -	43 19	5 27 E.	61 8
Mount Louis, in Rousillon,	42	2 40 E.	44 5
Cambridge, in New England,	42 25	71 W.	50 3
Philadelphia, - -	39 56	75 09 W.	52 5
Pekin, - - -	39 54	116 29 W.	55 5
Algiers, - - -	36 49	2 17 E.	72
Grand Cairo, - -	30	31 23 E.	73
Canton, - - -	23	113 E.	75 14
Tivoli, in St Domingo,	19		74
Spanish Town, in Jamaica,	18 15	76 38 W.	81
Manilla, - - -	14 36	120 58 E.	78 4
Fort St George, -	13	87 E.	81 3
Pondicherry, - -	12	67 E.	88
	South Lat.		
Falkland Islands, -	51	66 W.	47 4
Quito, - - -	0 13	77 50 W.	62

In high northern latitudes, as in Iceland, Hudson's Bay, and Greenland, a thick mist or fog hangs over them during the severity of winter: this serves to mitigate the rigour of that season. Vapour naturally contains a great quantity of caloric, and is otherwise a better conductor of that fluid than air: it is therefore well adapted for tempering the cold of those climates.

In proceeding from the equator towards the south pole, the temperature of the air is not so warm in summer as in corresponding latitudes of the northern hemisphere. This seems evidently owing to the greater extent of ocean in the austral division of the globe; but it is likewise probable, that the same causes which diminish the temperature of the atmosphere during the summer, will have the effect of rendering these latitudes warmer in winter than in similar latitudes on the opposite side of the equator. Æpinus and others suppose, that the lower temperature of the southern hemisphere arises in consequence of the shorter abode of the sun in the south tropic, which increases the length of summer over the northern division of the earth. Rocky soils, and countries in the vicinity of sandy deserts, are much warmer during summer, than others in the same parallels not so situated, and where the soil is covered with vegetables. The heat experienced in the deserts of Africa, is at all times so intense, that it almost entirely prevents the growth of every sort of vegetable matter. Similar situations near to the polar regions, are however found to be colder than places where the soil is different: thus, the countries around Terra del Fuego and the Straits of Magellan, have their temperatures much lower from this cause. Countries covered with forests are always colder in summer than such as are under cultivation. Large rivers and lakes have a similar effect as the ocean, but in a less degree, in modifying the temperature of climates: this is supposed to be a powerful cause in lessening the temperature of the air over North America. The situation of any district in respect to high mountains, will have its temperature varied accordingly: thus, places lying to the windward or north of a chain of hills, will have a much lower temperature that those to the lee, or such as have a southern or eastern exposure.

The temperature of the atmosphere over the ocean, differs considerably at all times from that which is in contact with the land, being usually lower in summer, and warmer during winter in temperate climates. The temperatures of seas vary from each other, and consequently their atmospheres must also differ in this respect. The heat of the ocean is never so warm in summer as the adjacent shores; on the contrary, in latitudes beyond the tropics, it is found to be of a higher degree of heat during winter. Indeed, the temperature of the land

and ocean with respect to each other, undergoes a variation every twenty-four hours; but this is most remarkable in warm climates. The smaller the extent of any sea, and the more frequently it is intersected by land, so much greater is its variations of temperature. The Atlantic Ocean being of great extent, has therefore the most uniform temperature throughout. On the contrary, Dr Kirwan supposes, that the greatest stretch of the Pacific Ocean being in the coldest regions of the globe, its temperature must be therefore greatly below the standard of the former; and the difference he estimates at five degrees. The German Ocean is about three degrees colder in winter, and five degrees warmer in summer, than the standard. At all seasons of the year, the Mediterranean, through its whole extent, is warmer than the Atlantic, which of course flows into it. A supply of water is likewise received by that sea from the current of the Euxine, which is always some degrees lower in temperature. The Adriatic, though warmer in summer, is so cold in winter, as to be frequently frozen over in the neighbourhood of Venice. Though the Baltic is much colder in winter than any other sea, yet in summer it is frequently heated to a degree equal in temperature to the Mediterranean at that season, being frequently so high as 70°, but continually varying with the temperature of the adjacent lands; its greatest temperature at mid-summer being from 48 to 56°. Lands from N. lat. 49 to 70°, have their temperature frequently so low as 40, 50, and even 70° below the freezing point, when the sea, even north of latitude 76°, has been never observed lower than four degrees under that point. The variations of temperature in the atmosphere, have been supposed to be accounted for by the existence of fire in the centre of the earth,—an opinion which has been of late years opposed with many irrefragable arguments; and it is accordingly generally agreed, that no fire can exist in the interior of the globe, in the manner the author of that opinion has supposed. It has been ascertained, that in temperate latitudes, the interior of the earth, and the bottom of the ocean, are always much colder than the temperature at the surface during summer; while, on the contrary, in winter they enjoy a greater degree of warmth. Were there really a fire in the bowels of the earth, instead of influencing the variations of climate, it would rather tend to make these more uniform through the different seasons of the year. Neither, by such an hypothesis, can we easily reconcile the idea of any region of the earth being at a temperature below the freezing point: the heat of springs of water issuing from the greatest depths, by no means proves that the interior is never cooled so low as 32°. On the other hand, every circumstance of the variation of temperature of climates can be satisfactorily explained, by the effects of the solar rays. Snow is generally supposed to be a medium well adapted for supporting the heat of the earth, when that of the air is cooled below the freezing point: it being a spongy mass, having its interstices filled with air, it is therefore a bad conductor of heat. M. Guetard found, that a thermometer, thrust deep into snow, stood higher than another exposed in the open air. From the above circumstance, it will be easily estimated, of what utility a covering of snow becomes, in preserving plants from the effects of very low degrees of heat.

The first accurate experiments that were made on purpose to ascertain the difference between the temperature of the air and soil, at different depths, are those performed by Dr Hales. The heat of the atmosphere and the surface of the earth was 80°, in August 1724; a thermometer placed two inches below the surface was 85°; and another at sixteen inches stood at 70°; while a third at twenty-four inches was only 68°: these two last retained the same temperature till the end of the month. On 26th of October, he found the air was 35° 5; two inches below the surface the heat of the earth was 43° 85; at sixteen inches depth the heat was 48° 8; and at twenty-four inches a thermometer stood at 50°. From the 1st to the 12th November, when the temperature of the air was 27°, a thermometer placed twenty-four inches below the surface, stood at 43° 8; but from March to September, the heat of the earth was constantly under the temperature of the atmosphere. The season had been very rainy, whereby a portion of the heat of the land had been exhaled from it, in the evaporation of the humidity. In this way we are enabled to comprehend why a wet summer must be succeeded by a cold winter. M. Raymond of Marseilles has found the heat of the soil so high as 160°, while the Mediterranean Sea was only at 77°. He has frequently observed also, the heat of the soil cooled down to 14°, while the sea was 44°; which was the lowest temperature at which he ever perceived it. These experiments decisively shew the causes of the difference in temperature between the atmosphere over the ocean and the adjacent lands. There are also several experiments made with a view to ascertain the heat of the earth and ocean at the greatest depths, and they completely disprove the opinion of the existence of a central fire in the earth, but uniformly tend to corroborate the observations of Mariotte, who found, that the earth was gradually heated during summer, and was as gradually cooled during winter.

The cave of the observatory at Paris, is ninety feet below the level of the street: its temperature remains nearly uniformly at 53°, and seldom varies more than half an inch, which is owing to its communication with the external air. In a mine in the neighbourhood of Boulogne 476 feet deep, the temperature is 54°. The salt mines of Wilickza in Poland, from 320 to 716 feet below the surface, have an uniform temperature at 52°. De Luc found, that in the copper mine of St John in the Hartz, at the depth of 1359 feet, the temperature was 50°, although, at the depth of 801 feet, he experienced the heat so high as 70°: And Monnet found the heat of the mine of Joachimstadt in Bohemia, at the depth of 1700 feet, permanent at 50°. Kraft observed the heat of a cave in Suabia to be permanent at 48°, the external air being then 66°, but the water in the cavern was only 42°.

The following table, from Dr Kirwan's Estimate of the Temperature of Latitudes, gives a view of the temperature of the earth and ocean at different depths,

Table of the Temperature of the Earth at different depths, and at various latitudes, by Mr Kirwan.

N. lat.	Season.	Temper. at surface.	Depth of feet.	Heat.
70°	May 12.	36°	502	39°
	17.	37	540	39
	June 9.	44	558	40
	July 7.	46	420	44
68	8.	47	1560	52
65	9.	48	1280	48
	10.	52	846	45
27	Jan. 3.	64	540	58
		84	13600 5346 }	53

Table of the Temperature of the Sea at different depths and latitudes, by Lord Mulgrave.

N. lat.	Season.	Heat of Atmosphere.	Depth of feet.	Heat of sea.
67° 35	June 20.	48° 5	4680	26°
78	30.	40 5	708	31
69	Aug. 31.	59 5	4038	32

By these tables we perceive, that the temperature of the ocean is always lower than the earth, in the same latitudes, during the warm season: and likewise, that at great depths, both in the land and sea, the temperature is much less than that of the atmosphere over them. But Dr Kirwan has ascertained, that from the difference of capacity alone in land and water for caloric, that the former takes always 8 or 10 degrees more heat than the sea in summer, and is 8 or 10 degrees colder in winter in the same latitude.—See Estimate, p. 40. Van Swinden mentions some experiments in proof of the accuracy of the above tables: a friend of his caused a pit to be dug within the polar circle, and at the depth of twenty-four feet the earth was found hard and frozen, but lower than this it was soft, the water liquid, and the thermometer rose to 54 or 56 degrees.

The theory of the general circumstances respecting the temperature of climates, depends on the properties of heat, which have been already explained, and the different degrees of power which the land and water possess of conducting this fluid. It has been formerly observed, that fluid and liquid bodies do not conduct the matter of heat so perfectly as those which are solid: the earth is therefore a better conductor of caloric than the ocean; it likewise reflects the sun's rays more powerfully, and is thereby more readily heated and cooled. In this way, the atmosphere over land is always found to be warmer than that over the ocean, during the immediate action of the sun's rays. The atmosphere over the ocean suffers likewise a considerable diminution of temperature during the influence of the sun. Water is but an indifferent conductor of caloric; but, when collected into a considerable mass, it has then a power of reflecting a portion of the rays which strike its surface. From this circumstance, the surface of the water speedily acquires a temperature sufficient to convert it into vapour; and thus, as its capacity for caloric becomes greater, it must of course reduce the temperature of the water contiguous to it, by depriving it of a portion of caloric. From this cause, the air over the ocean is commonly colder during the hot season of the year, than the atmosphere covering the land at a distance from the coast; and it is in consequence of this inequality of temperature, that the atmosphere moving from over the ocean forms a current towards land during day. This being colder and more dense, it naturally occupies the place of that which is warmer and more rarefied over the land.

In winter, when the sun's rays reach the latitudes north of the tropic of Cancer with a much greater degree of obliquity, the surface of the earth being more readily cooled than the surface of the ocean, and not being supplied with the usual portion of caloric at this season, its atmosphere suffers a corresponding diminution of temperature; but as the water of the ocean does not give out the heat it had acquired so readily as the earth, its temperature does not diminish so rapidly. Besides, as it penetrates to the greatest depths, it will thereby acquire the temperature of the earth at those places, which temperature is always higher than the freezing degree. The water at the bottom, on becoming warmer, on that account gradually ascends, having likewise become of less specific gravity: in ascending, it occupies the place of that portion which is of a lower temperature by being exposed to the atmosphere, and whose specific gravity being thereby augmented, it necessarily takes a direction downward. We therefore see, that by the continual motion of the water of the ocean, and the succession of warmer portions to its surface, in place of that which is cooled down to the temperature of the surrounding air, the atmosphere over the ocean must be warmer than that over land, in temperate climates during winter.

In winter, and during night also, evaporation is considerably diminished; therefore, heat is not so rapidly extracted from the ocean at those times; and the temperature of the air at the surface is, from the above-mentioned causes, always greater during the cold season, (whether annual or diurnal), than that over the land. By this theory, we perceive why the temperature of islands and maritime situations is warmer during winter, and cooler during summer, than continental situations under the same parallel of latitude. During night, the air over the ocean being warmer, a current is thereby established from the land: this, too, is most remarkable in warm climates.

The evaporation and quantity of rain that falls in any situation have a considerable influence in varying its temperature. Indeed, it is by the effects of these processes that many places within the tropics are temperated so as to become habitable. The cause of this will be easily comprehended, on the general principles of caloric already stated. We have observed, that the quantity of vesicular vapour which predominates in the colder regions of the north may tend to mitigate the rigours of the climate. This is probably owing in a great measure to its conducting power of caloric being greater; the temperature of this vapoury air being always found to be many degrees warmer, than the atmosphere at a little distance not impregnated with it.

Whatever tends to increase the proportion of evaporation, will have a corresponding effect to lessen the temperature of places; though it is not improbable, that fields under cultivation compensate for the heat abstracted by the transpiration from the crop, thereby communicating to the air a quantity of caloric equal to the loss sustained from this cause; every living substance possessing a certain permanent temperature, which depends on the operation of peculiar functions.

Whatever tends to lessen the evaporation from the surface of the earth, will proportionally cause an increase of its temperature: a soil of this description will likewise be found a better conductor of caloric. In this way, sandy deserts and rocky situations, in the vicinity of the tropics, are found to have a temperature raised to an excessive degree; while similar situations, near to the arctic circle, are found generally lower in temperature than the common heat of the latitudes in which they lie.

Thick forests, shrubs, and all sorts of growing vegetables, tend greatly to diminish the temperature of the atmosphere, in consequence of the evaporation from the surfaces of their leaves, and likewise by obstructing the calorific rays from reaching the ground. In this way, uncultivated tracts of land are found to be colder than such as have been for some time under improvement. America is said to have gradually become less cold during winter, as the forests with which it is covered are cut down, and the soil cultivated. It is likewise supposed, that the destruction of the forests in Germany has had a considerable effect in meliorating the climate of that country.

But there is no cause more powerful in varying the temperature of the atmosphere, than winds. When currents of air blow from a mountainous situation, or from a tract of country at a low degree of heat, its temperature being thereby proportionally diminished, it will consequently lower the temperature of the country over which it blows. In this way, a north or north-east wind renders the spring season over the coast of Britain extremely chilly: on the contrary, the temperature of the air all over the island is considerably augmented by an influx of air from the south or south-west.

Dr Kirwan supposes, that the heat of the atmosphere in winter is not so cold, at a short elevation, as the air immediately over the earth's surface. The soil being in that season colder, will cool the stratum of air nearest to it, contrary to what takes place in the summer season.

This circumstance must likewise occasionally occur in a partial degree in every season, in consequence of the reflection of the sun's rays from the upper surface of dense clouds: and in the same manner, whatever interrupts the sun's rays from reaching the earth's surface, must tend to diminish the temperature of the stratum of air immediately over it. These causes are generally watery vapours: the heat of the stratum of air above them will be thereby increased.

The circulation of the water of the ocean has also a powerful effect in modifying the temperature of climates without the tropics. Independently of casual agitations or regular periodical movements, it has been ascertained to flow constantly westward; and the tendency to this direction is strongest the farther west. Water flowing from a warmer climate, will communicate the heat it had acquired, as it proceeds towards the poles. In this way, it has been supposed, the temperature of the British Isles is rendered milder in winter than the parallel latitudes on the continent; and these, again, are found to be warmer, owing to this cause, than similar latitudes in Asia. The air in contact with a medium of superior temperature, as the water of the Atlantic ocean is known to be during winter, imparts a genial warmth to the soil when it blows over land; but it is soon deprived of this superior degree of heat, and speedily acquires the temperature of the regions over which it spreads: the temperature of the soil being extremely low, for a great part of the year, in the North of Europe and Asia, it thus tends to depress the heat of the climates all over the eastern coast of that continent. Hence, the western coasts of Europe are habitable even as far as the 70° N. lat. while, on the eastern shores of Asia, population does not reach beyond the 56° N. lat.; and for the same reason also, the east coast of Asia is much lower in temperature than the opposite coast of America, the winter being as severe at Canton, 23° 30', as at Charlestown, 32° 45′, N. lat. And in general, it is to be observed, that the western coasts of all large islands are much warmer in winter, and have a higher mean temperature, than places on the eastern shores, (see Blagden, Phil. Trans. 1781); the warm vapoury air depositing its heat as it spreads into the interior, where it acquires the lower temperature of the place.

It was originally remarked by the Hon. Mr Boyle, that even in tropical climates, the air during night is much colder at the earth's surface than at a few feet of elevation. This has been confirmed by Mr Sex of Canterbury. He performed a great variety of experiments in order to determine this fact, and he uniformly met with the same general result. There cannot be a complete explanation of this circumstance, without being made acquainted with the state of the weather previous to, and at the time of performing the experiments. The greater coldness of the stratum of air nearest the earth, may be principally owing to the absence of the sun's rays, whereby less caloric is communicated to it: but the coolness of the soil will be likewise augmented by the precipitation of vapour from the atmosphere, which always begins to fall on the disappearance of the sun from the horizon; and as the soil still retains, at that season, a considerable portion of the caloric it had acquired in the day-time, a quantity of the condensed vapour will be again elevated in its elastic state, as soon as it reaches the earth's surface, and, by absorbing a portion of its heat, a corresponding diminution of the temperature of the atmosphere will follow. This explanation agrees in every respect with the account of the experiments themselves; the difference of temperature being found to be greatest in the early part of the evening: then the soil is warmest, and the precipitation of dew most copious. It declines somewhat toward morning, the heat of the earth being then lowest, and the vapour wholly condensed.

Professor Wilson of Glasgow gives an account of some similar experiments performed in the winter season: but the result was different from the above. He found, that the surface of snow was always several degrees warmer than the air at an elevation of four feet: but this difference only took place during the formation of hoar frost. The explanation of this circumstance seems to be founded on the doctrine of heat already stated.

Snow has been found to be a bad conductor of heat: it is therefore always warmer than the atmosphere over it. During the intenseness of cold frosty weather in winter, vapour does not rise high above the surface; probably it rarely exceeds the space indicated by Mr. Wilson's experiments. It becomes condensed on the setting of the sun; and acquiring the form of hoar frost, the heat it contained in its former state will be then extricated, and of course, the temperature of the air in which it abounds will be increased. It seems to have been owing to the extrication of latent heat, from the vapour being dispersed over a wider range, that Mr. Wilson always perceived the temperature of the air uniform at both points, when the atmosphere happened to be obscured by fogs.

SECT. IV.

OF THE SUPPOSED CHANGE OF CLIMATES IN CERTAIN COUNTRIES.

It has been a question frequently agitated, whether the temperature of climates be the same at the present period as they were in the early ages of the world; or whether those changes which are occasionally remarked be not periodical, and unconnected with local causes. But the limits of this work do not permit a tedious historical investigation of the subject. We shall therefore confine the observations we have to offer respecting this question, to such facts as seem most intimately connected with the foregoing remarks on the nature of climate in general; or which serve us in elucidating some circumstances respecting the climate of Great Britain. We have already endeavoured to show, that the atmosphere acquires its temperature in consequence of the reflection of the sun's rays from the earth's surface, and by its lower stratum being in constant contact with a medium whose temperature is raised by the absorption of caloric from this source.

Considering the permanent influence of the common source of atmospherical temperature, we should naturally expect to find it constant and uniform through similar seasons of various years; and were it not for the operation of certain powerful causes, no other deviation would occur, than such as may originate from the position of this globe in respect to the general planetary system. Many of the causes which induce variations of atmospherical temperature, seem to act by an immediate and transitory operation. The effect of other agents in altering the temperature of the atmosphere is more gradual, permanent and powerful: the only cause of this kind which is best known to us is the sol lunar influence, by whose effects accumulations or tides of the atmosphere occur periodically; and it is perhaps especially owing to this power, that differences of atmospherical temperature in similar seasons of different years do occur. The proportion of aqueous vapour existing at any time in the atmosphere, depends entirely upon its temperature, which has also a considerable influence in varying the direction and force of the wind; and we shall afterwards find, that from these effects the temperature of the atmosphere itself is liable to suffer the most considerable variations.

Italy is found to be much warmer than it seems to have been in the time of the first Roman Emperors: the winters in the south of Europe were then much more severe, according to the concurring testimony of every author. Diodorus Siculus mentions, that the rivers in Germany and in Gaul, as the Danube, the Rhine, &c. were always frozen during winter; and that it was found necessary to cover the ice with straw, in order to render the passage over them secure. Nevertheless, during the most severe winter that has occurred during last century, (1795), there was no river of any consequence frozen over, even in the northern parts of France. Ovid takes notice of the freezing of the Euxine during winter, in the tenth elegy of his Tristia: from the account he gives of the circumstance, it would likewise appear, that this sea continued to be sometimes covered with ice even through the summer. There are likewise authorities which shew that it was not unusual to find the wine frozen by the cold of winter in the south of Europe. A similar fact is stated in several places of the Scotichronicon: the author expressly says, it was then sold out by weight. Pliny the Younger had a country house in Tuscany, where neither olives, myrtles, nor any sort of plant which requires a warm climate, could be raised: but it is found, that in this situation all these fruits come to the greatest perfection by the ordinary temperature of the climate of the present day. By the writings of Virgil and of Juvenal likewise, it appears evident, that the cold of Italy in the winter must have been much more severe in their days than what we find it to be in the present times. The former gives minute instructions for protecting the cattle from the inclemency of the season. The other affords us a proof that the Tiber must have been commonly frozen over during winter in those times, as he records the ceremony performed by a person who was under the necessity of breaking the ice of this river, in order that she might be enabled, by means of its waters, to celebrate certain superstitious rites. No such occurrence has been known to take place within the present æra.

Ths chief cause which is supposed to have effected so remarkable a change in the climate of Italy, has been imputed to the draining of marshes, the cutting down of forests, and putting the soil into a proper state of cultivation. This practice, in countries adjoining to Italy, as in Germany, must have had a considerable influence in meliorating its climate; but there is no doubt, but that in the days of Augustus the soil of Italy was in a much higher state of improvement than it has been for these many ages past; nevertheless the climate appears to be much milder than it was during his reign. We therefore cannot ascribe this alteration in its temperature to any circumstance connected with agricultural improvements. Besides, some of the historians and poets of the earlier periods of the Roman history seem to think, that at a time much anterior to that in which they lived, the seasons of Italy and of Greece were much more mild. This alteration of atmospherical temperature is plainly indicated in lib. 1. cap. 1. of Columella's work *De Re Rustica:* he there remarks, " Multos enim memorabiles auctores comperi persuasum haberi, longo ævi situ qualitatem cœli statumque mutari :—nam (Saserna) ex libro quem de agricultura scriptum reliquit, mutatum cœli statum sic collegit, quod quæ regiones antea propter hiemis assiduam violentiam nullam stirpem vitis, aut oleæ depositum custodire potuerunt, nunc mitigato jam et entepescente pristino frigore, largissimis olivitatibus liberique vendemiis exuberunt."

When Cæsar invaded Britain, he found the harvest finished, except in one field; and according to the opinion of Dr Halley, he must have landed upon the 14th of August, N. S. This island was then overgrown with wood, which, for the reasons we have already stated, must have rendered its temperature much less warm than if the soil had been cleared, and under a proper course of cultivation; nevertheless Cæsar remarks, that the temperature of the climate of Britain was then milder than that of Gaul. He mentions, that the inhabitants went about unclothed,—a circumstance which amounts nearly to a proof, that the temperature of its atmosphere must have been then higher. Cæsar likewise mentions, that corn did not ripen in the northern provinces of Gaul on account of the cold. But we have still other circumstances no less distinct, which show, that the winters must have been much colder in Europe, even in latter times, at an æra not very distant from the period in which we live: this is to be presumed, from finding that the lesser seas were more commonly frozen over in winter. It is recorded, that in 1668, the Baltic was so firmly frozen, that Charles XI. of Sweden transported his army across it. It is likewise mentioned by Glycus, an historian, that in 775 the Mediterranean was frozen along the coast to the distance of fifty leagues; and the Adriatic, which was commonly frozen in the winter during the time of the Romans, has not been found in that state since the cold winter of 1709. According to Cæsar, the rein deer, the elk, and the wild bull, were common in Germany, being sheltered by the Hyrcanian forest. The first-mentioned of these animals is in the present day only to be found within the polar circle. In the days of Aristotle, the climates of Gaul and of Scythia also were so cold, that the ass could not thrive in them. Pliny says also of this animal, " ipsum animal frigoris maximi impatiens igitur, non generantur in Ponto." In all these climates, the asses are found at present, not only in plenty, but also very handsome and docile. Tacitus, in his Life of Agricola, gives also a favourable report of the temperature of the climate of Britain. He says, " Solum præter oleam vitemque et cætera calidioribus terris oriri sueta, patiens frugum, fecundum, tardo mitescunt, cito proveniunt." *Vita Agricolæ*, 66. Elziv. ed. 1640. In 278, the Emperor Probus promulgated particular instructions respecting the planting of vines in this island, and of making wine,—a sure proof that its climate was then thought of sufficient temperature to bring this plant to maturity.

It is rendered evident by the discovery of immense quantities of the largest sized wood under the mosses, that this country has been capable of raising wood, in former times, far exceeding the size of that raised in the present day; and it is no less certain, that these woods have grown in situations where the most hardy shrubs will now scarcely vegetate.

The growth of the mosses themselves, is likewise a proof of this melancholy change in the temperature of our atmosphere, as they are only found in a cold climate; and the origin of many of those in Britain, can be easily traced to the felling of the woods by the Romans; and in the northern parts of the island, to the same practices, followed by the English, in their endeavours to dispossess the Scots of their fastnesses. It would appear also, that our highest hills were formerly covered with growing wood; which probably decayed with the diminished temperature of the climate. "Trees have often been found deposited near the summits of many mountains, at heights in which, from the degree of cold which at present prevails on them, they could not now grow; therefore, they must have grown when the temperature of these summits was warmer, and consequently when they were less elevated over the surface of the sea, and less distant from it.—See Kirwan's Geological Essays, p. 36. But, reflecting on what Herodotus says respecting the Nile more than 2000 years ago, and comparing it with the appearance of the shores of that river as it now exists, the difference is so extremely trifling, that we are not inclined to think, that any remarkable alteration of climate has occurred from this cause; the bed and level of the ocean having seemingly undergone but a trifling variation for these many ages past.

From this cause also, it has been supposed, that several species of animals, which were formerly common in this country, are not now to be seen; others have evidently degenerated. The deer of the present times seems but a puny animal, in comparison to those which existed in this island at a former period: this we persume to be the case, by comparing the size of their horns with those dug from under the mosses. In like manner it would appear, that our breed of black cattle must have been different, and of a much larger size. The decrease of the temperature of the climate of Britain, is likewise evinced by circumstances connected with the agriculture of the country. Hemingford, according to Andrews, mentions, that at the siege of Dirleton Castle, the English soldiers on that enterprize must have starved, had they not been supported with the peas growing in the adjoining fields: this took place in the beginning of July 1298, and gives a pleasing idea of the agriculture of East Lothian at that early period. At the present day, peas do not ripen in the same fields till fully six weeks later. In the time of William of Malmsbury, who died about 1148, the culture of the vine had arrived at such perfection in England, particularly in the Vale of Gloster, that wine was made in abundance, and little inferior in quality to that of France. It is probably owing to a diminution of the temperature of the climate, that of late years it has been found so difficult to raise certain species of apples in the cyder counties of England, which were formerly easily cultivated. By inspecting the statistical records of Scotland, it appears, that wheat was formerly paid to religious houses from lands where it is now impossible to raise that grain, and where it has not been attempted for nearly these 200 years. There was paid yearly, twelve bolls of wheat, besides a quantity of barley, to the Monastery of Glenluce, from a farm in the parish, which, some years ago, was thought high-rented at L. 12 Sterling. It likewise appears, from consulting the historians of Scotland, that a considerable export trade in grain was carried on from Leith, even during the sixteenth century. —See Fragments of Scotish History, *passim.* And it seems probable, that more grain was raised in this country in the commencement of last century, than is cultivated at the present time, even in the improved state of agriculture. The marks of the plough in many situations now quite barren, and which have not been laid down within the memory of man, seem to confirm this opinion. Sir Robert Sibbald, in his Scotia Illustrata, dedicated to Charles II., has the following observations respecting the fertility of the country at that period: he says, " Segetes tanta fœcunditas, ut muneribus utriusque sufficiat et cereris et liberi: magna quoque quantitate ad exteras exportantı r." This author agrees with Scaliger, whose words he quotes, he having remained some time in Scotland, and speaks very highly of the abundance and quality of its grain, but especially of its wheat, and the superior fineness of the bread. He likewise mentions the vine as a plant that was common in Scotland at that period. The correctness of this statement is put beyond doubt, when we consider the very provident regulations respecting the growth of certain crops, passed in the reigns of the earlier Jameses. Even within the memory of many persons, the climate of the northern part of Britain has declined in temperature, since about the middle of last century: at that period all the agricultural operations were performed earlier in the respective seasons. When preparing the soil for the barley crop in April, it was customary to yoke the plough very early in the mornings, as the heat usually became so great about eight o'clock, that it was found necessary to leave off work till the afternoon, when the warmth of the meridian sun had abated. From these instances it is evident, that the climate of Britain has suffered a considerable change within these two last centuries; probably, however, the annual temperature is not really diminished; as, according to common observation, although the summers are not now so warm as formerly, neither are the winters so cold, as they were experienced fifty or sixty years ago. Dr Williamson, in his essay upon Climates, published in the American Philosophical Transactions, remarks, that the seasons in Pensylvania have changed greatly within these last fifty or sixty years; the temperature of the winter being milder, and the summers much less warm.

From Mr Jefferson's notes on the state of Virginia, it appears, that a remarkable change in the temperature of that climate has lately supervened: this author observes, that "a change in our climate, however, is taking place very sensibly. Both heats and colds are become much more moderate within the memory of even the middle aged. Snows are less frequent and less deep; they do not lie below the mountains more than one, two, or three days, and very rarely a week. They are remembered to have been formerly frequent, deep, and of long continuance. The elderly inform me, that the earth used to be covered with snow about three months in every year. The rivers which seldom failed to freeze over in the course of the winter, scarcely ever do so now. This change has produced an unfortunate fluctuation between heat and cold in the spring of the year, which is very fatal to fruits." This evidently shows, that the climate of America is undergoing changes similar to those which are taking place in that of Britain.

M. De Luc seems to think, that the Glaciers are receiving an annual augmentation. The Abbé Richard gives many instances of a similar diminution of temperature having taken place in the climate of France. He mentions a district where the vine was cultivated successfully about 230 years ago, but where, in consequence of the increasing cold, grapes do not siderable diminution of temperature, even within these last hundred years: it was formerly capable of raising grain sufficient, or nearly so, for the consumpt of its inhabitants; but at present the valleys that used to be formerly laid down in corn fields, are now become bleak and waste, and during the greatest part of the year they are covered with snow. There is hardly any corn raised at present in any part of the island: its temperature has decreased so rapidly since about the middle of the last century, that Torfeus, a native of Iceland, says, in his history of Norway, that he perceived many melancholy changes in the face of that country, in consequence of the increasing cold of the climate, even after an absence of but a very few years. There appears to have been formerly several plantations of wood in Iceland; at present there is hardly a tree to be seen through its whole extent; and it is with seeming difficulty even the hardiest shrubs continue to vegetate. East Greenland was long ago much resorted to by the Danes, for the sake of commerce, and then the temperature of its atmosphere does not appear to have been very severe; but all at once an alteration in this respect seems to have taken place in it, and for these two or three centuries its coasts have been found inaccessible, on account of the shoals of ice; and the interior of the country, even in the middle of summer, lies buried in snow. It seems likewise to be generally admitted, that within the course of last century, there has been a considerable increase of ice around the polar regions. It has even been said, that the sea at the north pole has been repeatedly navigated, towards the commencement of the last century; but, at present, it is found inaccessible beyond N. lat. 80°, on account of immense shoals of ice. Whatever the causes may be which occasion a change in the temperature of the climate of any country, they must necessarily produce a similar effect on other countries adjoining to it. It is therefore to be presumed, that those causes which have had so remarkable an effect in causing the accumulation of ice in the polar regions, and of lowering the temperature of the climates of East Greenland and Iceland, in so remarkable a degree, must have had a proportionate influence in altering the climate of Britain, and probably of the entire hemisphere, north of the equator. What these precise causes are, it is impossible to say; whether they depend upon a concurrence of circumstances, such as we have already spoken of as effecting partial variations of climate, and confined to the globe itself; or if the instances of variations of the temperature of climates which we have specified, should be referred to the position of the earth, in respect to the general planetary system, we have not a sufficient number of facts to warrant us to determine. Lord Dreghorn says, that Linguet has ascribed the commencement of the colder seasons in Europe to the time of the earthquake in Lisbon in 1756,—an observation which has likewise been made by other well-informed people. M. De Humboldt, in his travels through South America, found, that the temperature of the air at Quito had considerably diminished since the great earthquake in 1797, the thermometer being now commonly 41° to 54°, and it seldom rises to 68°; whereas, when Bouguer visited that country, he observed it constantly at 66° or 68°.

The coincidence of these effects from the operation of a similar cause, would lead us to suppose, that the alteration of the temperature of climates somehow or other depends upon these great convulsions of nature; but we are only able faintly to trace these effects; we have no possibility of unravelling the manner how this alteration is produced.

Dr Williamson imputes the change which has taken place in the climate of America to the clearing of the ground, and bringing the soil into a state of cultivation. This opinion has also been embraced by others, and particularly by Mr Williams, in his work on the climate of England. At first view, there does not appear the slightest objection to this opinion of the matter; it naturally follows, that wherever the surface is cleared of the thick forests, as in America, the temperature of the air will become milder. But granting this to be the cause of the superior mildness of our winters within these few years, does it not follow, that this cause should also give rise to a corresponding increase of our summer heats? This we have seen is however not the case; the temperature of the atmosphere in summer having become of late years much colder. We therefore presume, that our agricultural improvements have had no influence in causing these peculiar changes of the temperature of the climate of Britain. Indeed, it is extremely problematical, whether the ordinary operations of husbandry, even when carried to the highest degree of improvement, have much influence in altering the temperature of the atmosphere. The soil of the northern part of Britain, was never in so high a state of improvement as in the present day; yet we have seen a regular succession of bleak cold springs and summers supervene under all these circumstances; and if we consider the great disproportion between the natural and cultivated grounds in every country, we must be still more persuaded of the insufficiency of the cause thus assigned, for explaining an effect which seems so general. The Abbé Mann, in his essays on the Changes of the Temperature of Climates, in the Manheim Transactions, says, that from the most careful research into the histories transmitted to us from the ancients, it appears, beyond any doubt, that the soil and temperature of the lands from Spain to India, from Mount Atlas to Lapland, and the remote northern regions, since the period of the earliest historical records, have been gradually changing from a state of great moisture and coldness to a superior degree of dryness and warmth. The Abbé supposes this has been principally brought about by the clearing of the grounds of trees, draining the morasses, and by cultivating the soil; and we therefore now find countries possessing the most genial climates, which in the time of the Romans were nearly not habitable for cold.

The author of the memoir above mentioned, who signs his name De Vivarais, supposes the decreasing temperature of Europe is gradually increasing, in consequence of the precession of the equinoxes, and the declining obliquity of the ecliptic. We do not mean to object to the effect which this might produce, in making a less difference between the temperature of winter and of summer: but it seems probable, that the instances of changes of atmospherical temperature which we have adduced, have been too rapid to admit of explanation by the operation of a cause so extremely gradual and protracted. At any rate, although, from this cause, the temperature of the different seasons would be rendered more equable, it does not appear how this should operate in rendering the winter warmer, which is evidently the case, according to the facts we have adduced: on the contrary, the cold of winter should be expected to become still more intense, and with a corresponding diminution of the temperature of summer. However, that an alteration in the temperature of climates has formerly taken place, from the nutation of the earth's axis, has been inferred from circumstances especially connected with geological observation: the remains of animals and vegetables, which are only natives of the warmest regions of the earth, have been found in very high northern latitudes; while, on the contrary, none of the remains of animals or plants natural to a cold climate have ever been discovered within the tropics. It has been therefore imagined, that from this cause the poles are continually shifting, and that, consequently, they may at some former period have been in the present situation of the equator. This is an hypothesis which is rejected by astronomers: "The pyramids of Egypt demonstrate, that the poles have remained unaltered these three thousand years."

When we come to treat of prognostics of the weather, it will then be made to appear, that the seasons undergo changes corresponding to others recurring at certain periods, and which seem to be produced from the connection of the globe with the other planets. In this way, it does not seem improbable, that similar effects should result from the operation of similar causes acting at a longer interval. This appears to be the most probable cause of the changes of climate; and it seems to receive confirmation, by considering the stated alterations which have taken place in the climates of Europe, according to the authorities we have adduced. These most probably undergo an alternate increase and diminution of temperature for a certain period of years. Many of the older writers have fixed this period to the revolution of six hundred years,—a period particularly alluded to by Pliny in his natural history, and which has been more particularly explained by Professor Burja, of whose opinions upon this question there is an analysis in the 1st vol. Philosophical Magazine.

But although we are unacquainted with those causes which have occasioned the extraordinary diminution of temperature in the latitudes near to the pole, within the course of the last century, there cannot, however, exist any doubt, that this diminution of temperature in the higher northern latitudes, has occasioned the remarkable difference of the temperatnre of the seasons of late years in Britain. The accumulation of ice around the pole in the winter, being more than can be dissolved in the short space of summer weather, it must be constantly receiving an annual increase. The atmosphere over these regions, therefore, will become proportionally more dense, from being in contact with a medium cooled down to the lowest degree; and, in consequence of this increased density, it will be confined much nearer to the situation where these accumulations of ice and snow do exist. Thus, in winter, when the northern hemisphere declines from the plane of the ecliptic, the atmosphere, in consequence of its increased gravity, will recede from the equator northward; and naturally falling toward the most declined point, it will gradually accumulate about the pole. In this manner, the regions within the arctic circle will be chilled to the very lowest possible degree, from being surrounded with this cold dense atmosphere. It seems owing to this circumstance, that the equatorial current blows over Britain in winter with greater constancy, not being interrupted in its course northward: and in this manner, the temperature of its climate is kept higher than it otherwise could have been. In the spring season, when the northern hemisphere begins to be inclined towards the equator, this inclination giving a greater facility to the motion of the polar atmosphere, it rolls down the plane of the earth with increased force, to occupy the place of the more rarefied air in the vicinity of the tropics, and which opposes little resistance to its descent, in consequence of its higher temperature, from the immediate influence of the sun's rays. The polar current continues therefore more permanent and steady, in proportion to the difference of its density, and that of the mass of air it displaces.

In this manner, we are able to comprehend how the spring and early part of the summer seasons in Britain are found to be frequently colder than at any other period of the year.

It may be objected, that the difference of 23½ degrees of declination from the perpendicular position of the earth's axis, in its annual revolution, is too trifling to cause the effect we have supposed: but, considering that the peculiar figure of this globe is that of an oblate spheroid, we can have no doubt of its efficiency in this respect. The opinion we have offered certainly accords with actual observation, and will be found to correspond with the most correct meteorological tables.

CHAP. III.

OF METEOROLOGY.

SECT. I.

OF SPONTANEOUS EVAPORATION, AND ITS CAUSES.—OF RAIN, SNOW, HAIL, WATER-SPOUTS, AND OTHER METEORS CONNECTED WITH THE EXISTENCE OF WATER IN THE ATMOSPHERE.

By endeavouring to ascertain the cause of the evaporation of water, and its consequent elevation into the atmosphere, an explanation has been obtained of many circumstances of the highest importance in meteorology; and, on this account, it became a favourite subject of discussion during an early part of the preceding century, with those engaged in the investigation of the natural properties of the air. Water abounds so copiously in the atmosphere, that Dr Boerhaave, and even the illustrious Priestley amongst the moderns, imagined, that it constitutes one of its intimate component principles. But more recent discoveries, and some of these even divulged by Dr Priestley himself, have convinced philosophers that this opinion is unfounded; and it is now fully ascertained, that water exists in the atmosphere as a matter equally foreign to its composition as any other vapour found occasionally mixed with it.

It is rendered evident, that the vapour contained in the atmosphere must have originated from the earth's surface. By exposing a quantity of water to the open air, it is perceived to diminish rapidly in bulk, and at length entirely to disappear. It is also to be observed, that this circumstance takes place in the most frigid, as well as in the warmest climates; although in the latter, the proportion of water that disappears is much greater than in the former situations. Water likewise evaporates much faster during summer than in winter, in every climate; nevertheless it has been ascertained, that even ice, during a north wind, and when the temperature of the air was very low, lost considerably by evaporation. According to the observations of De Mairan, it took place in the proportion of six grains to a cubic foot in the course of an hour. Wallerius found, that ice evaporates in proportion to its surface and temperature, though less than water equally cooled; and Saussure found, that it evaporates in air four or five degrees colder than itself.

The ingenious Saussure has also found, that the evaporation of water is quicker in proportion to its height in the atmosphere: this, as has been already pointed out, is in consequence of the diminished pressure on its surface. He discovered, that the boiling heat of water on the summit of Mount Blanc was 186°, the barometer standing nearly at 17 inches; and at a height of 10,000 feet above the level of the sea, the evaporation took place in proportion of 7 to 3 of water converted into steam, in the latter situation. He likewise ascertained, that in an atmosphere increased in rarity one-third, the evaporation is double the rate of diminished gravity. The evaporation of water is likewise greatly increased by wind: this is partly occasioned by the increase of surface, in consequence of the water being agitated by the current of air passing over it; but the proportion evaporated, according to the degree of velocity of the wind, is not yet determined. Saussure found, by experiments performed at Geneva, and on the Col de Geant, that wind moving at the rate of 42 feet in a second, triples the quantity of evaporation in calm air. Dr Kirwan observes, that in the British isles the evaporation is about four times greater from the vernal to the autumnal equinox, than between the autumnal and vernal; that other circumstances being equal, it is so much greater as the difference between the air and that of the evaporating surface is greater; and so much smaller as the difference is smaller; and therefore least when the evaporating surface and the air are both at the same temperature. But, if the air be 15° colder than the evaporating surface, there is scarce any evaporation at all; on the contrary, moisture is deposited. But according to Richman, if the water be only 11° colder, it will evaporate, though slowly; and evaporation is always briskest when the inferiority amounts only to $1\frac{1}{2}$° or 2°: but when the air is the coldest, the reverse takes place; the evaporation being greater, as the difference between the temperature of the air and that of the water is greater. The evaporation is also greater in proportion as the atmosphere contains less vapour; and cold produced by evaporation, is always more intense when the atmosphere is warmer. But it is Mr Dalton who has examined the subject of evaporation with most accuracy: he conducted a set of very correct experiments, in order to determine the proportion of water evaporated at different temperatures; having previously ascertained by experiment, what degree of pressure on the surface allows it to boil at a given temperature; and from these he has constructed the following table.

Heat of the water when boiling.	Pressure upon the surface in inches of mer.	Rarefaction of the air.
212°	30 0	1
200	22 8	1 3
190	18 6	1 6
180	15 2	2
170	12 2	2 45
160	9·45	3 2
150	7·48	4
140	5 85	5 1
130	4 42	6 8
120	3 27	9 2
110	2 52	11 9
100	1 97	15 2
90	1 47	20 4
80	1 03	29

He next ascertained the quantity of evaporation, by filling with water a cylindrical tin vessel of the diameter of 3¼ inches and 2½ inches in depth, which he kept boiling over a fire with a moderate draught of air: he found, that it lost 35 grains in a minute. When he performed the experiment in a room where the draught of air was precluded, it lost only 30 grains in the same time: when the draught was stronger, and the fire brisk, the loss by evaporation was 40 grains; and when both the draught and fire were increased, he supposes the evaporation might amount to 60 grains. " The evaporation from water of 180° was from 18 to 22 grains *per* minute, according to circumstances, or about one-half of that at 212°. At 164° it was one-third of the quantity at the boiling temperature, or from 10 to 16 grains *per* minute. At 152°, it was only one-fourth of that at boiling; or from 8 to 12 grains, according to circumstances. The temperature of 144° afford one-fifth of the effect at boiling; 138° gave one-sixth," &c. And he likewise found, that the forces of vapour at 212°, 180°, 164°, 152°, 144°, and 138°, were equal to 30, 15, 10, 7½, 6, and 5 inches of mercury respectively.

It has been already remarked, that the gravity of the atmosphere considerably opposes the process of evaporation; but this is overcome by the superior elasticity of the vapour, which it always possesses in a degree corresponding to its temperature. By the above table, the quantity evaporated at a certain temperature may in general be easily determined; as it is in proportion to the quantity evaporated from the same surface at 212°, as the force of steam of the former temperature is to the force of that fluid at 212°. Mr Dalton has in this manner calculated the force of the vapour of water at different temperatures. Those he has reduced into the form of tables, which he has found applicable to the evaporation of all other liquids.

It is extremely difficult to ascertain the quantity of vapour which a definite measure of atmospheric air can hold suspended, as the point of saturation must be continually varying, by temperature, pressure, and probably through the agency of electricity. M. Saussure has shown, that at the temperature of 66°, a cubic foot of air can retain from 11 to 12 grains. Mr Dalton has investigated this subject by a more extensive series of experiments, and calculates the elasticity of vapour by the rise of the mercury in the barometer; and from these he drew up a table, by which he points out the proportion of vapour in the atmosphere at every temperature. He found that in Britain, during summer, the vapour in the atmosphere rarely elevates the quicksilver 0.6 of an inch, though frequently it amounts to half an inch; and in winter, it is sometimes so low as only to raise the barometer 0.1 of an inch, while in the torrid zone it varies from 0.6 to one inch. Fontana long ago observed, that the proportion of vapour contained in the air depends on the quantity of caloric with which it is united; and that by this means it may be made to occupy a space 20,000 times greater than what it did in the state of water; or even double that extent, according to Ingenhousz.

Mr Dalton has discovered, that when vapour is mixed with any gas, its bulk is then considerably increased, and always in proportion to the temperature of the vapour; so that the space it occupies may be augmented to any volume. But according to the experiments of Landriani, when vapour mixes with the air, its volume is increased in a much greater proportion than what should take place: from thence its specific gravity goes on decreasing, according to the quantity of water it contains. Mr Dalton has likewise shown, that the properties of vapour, when mixed with the atmosphere, remain unimpaired; and he employs a very simple method of ascertaining its elasticity in that state, which was originally suggested by M. Le Roi. He uses a tall cylindrical glass jar, which must be filled with cold spring water, if the experiment be performed during the hot months of summer; and in winter, the water must be previously cooled below the temperature of the atmosphere. When the vessel is filled, should there be any precipitation of dew on its outside, he directs the water to be poured out, letting it remain till it has acquired a small degree of heat: it is then to be poured back into the jar, marking again the formation of dew on its outside; and he continues to pour out the water till the condensation of vapour is no longer perceived to take place in this way: the temperature of the water in the jar, indicates the heat of the vapour in the atmosphere. This is certainly a very ingenious, and an accurate method of ascertaining the elasticity of vapour in the atmosphere; though it appears, that the experiment may be performed with equal exactness, and with less trouble, by allowing the water to remain in the jar, carefully wiping the outside occasionally, till moisture is no longer deposited on it. This must be done in the open air, or at a window, because the air within is generally more humid than that without doors.

There are many causes which produce a variation in the proportion of water evaporated, even when the temperature and gravity of the air continues uniform: thus, we have already observed, that winds, from whatever point they blow, increase evaporation, which is again diminished during settled weather. The spontaneous evaporation of water will likewise depend considerably on the quantity of vapour previously existing in the air; and its degree of elasticity will likewise have a considerable effect. But as the elasticity of the vapour in the atmosphere will seldom be so great as the elasticity of that which is rising from the surface, evaporation must therefore be continually going on. Abbé Richard observes, that evaporation goes on even during the fall of rain; at least, this process succeeds so rapidly to its fall, that it is impossible to distinguish at what period evaporation commences. But as the elastic force of the vapour mixed with the atmosphere approaches to that of the vapour rising from the surface of the earth, evaporation must suffer a proportionate diminution. As evaporation can only take place at the earth's surface, the atmosphere is found to be drier the higher we ascend in it. It has likewise been observed, both by

Saussure and De Luc, that the atmosphere, at the same height, is drier during night than through the day. This is probably occasioned by the state of the lower air becoming more dense, in consequence of the absence of the sun's rays, and the entire column of the atmosphere being thereby proportionally shortened.

There are many ingenious contrivances for ascertaining the degree of humidity in the atmosphere; and, on this account, they are denominated hygrometers. These are all formed on the property which certain substances have of imbibing humidity: amongst these, the beard of the wild oat (arista avenæ fatuæ) has been suggested for this purpose. Mr Boyle recommends a bit of dry sponge, fixed in a delicate gold balance, twisted ropes, thin slips of leather or wood, as of poplar, oak, willow, &c. These indicate a moist state of the atmosphere, by having their dimensions enlarged by the absorption of moisture from it. Chemistry has likewise made us acquainted with several matters possessed of the property of absorbing water from the air; such as acids, alkalis, some neutral salts, sulphurets, &c.; but these have been all superseded by the ingenious contrivances of Saussure and De Luc, which are not only more accurate, but they are also convenient in other respects. The hygrometer of Saussure is constructed so, that the indication moves by the contraction and elongation of a human hair, previously baked, That of De Luc, which by many is thought to be preferable, has the indicator to turn round the index by means of a very thin slip of whalebone, previously well dried. The fixed points of every hygrometer ought to be that of extreme dryness and extreme moisture; but it is to be regretted, that these extremes cannot be readily determined. It is perhaps impossible to free any portion of the atmosphere completely of vapour; neither can its point of saturation be obtained more easily. The index both of Saussure's and De Luc's hygrometer turns round a scale divided into a number of parts, according to the fancy of the inventor: that of Saussure has 100 degrees. The extreme points are ascertained in the best possible manner, by leaving the hygrometer for some time in a portion of air rendered as free of moisture as possible, by means of salts and the electric shock. The gradation of the instrument must be performed in air whose temperature is uniform and low: the point at which the indicator stands is marked the beginning of the scale. The hygrometer is next immersed in a portion of air rendered as humid as possible by the addition of vapour; and the point at which the indicator stands forms the other end of the scale. The construction of either of these instruments is very difficult, and, on that account, can seldom be relied on as being minutely accurate. For a more particular description of them, we refer to Saussure's

Essai sur l'Hygrometrie, and to the different meteorological writings of Cotte and De Luc.

The hygrometer is an instrument of the greatest utility, in a practical point of view, to the chemist, physician, and agriculturist. By its indications, the variations of chemical processes can be explained, or their consequences perhaps prevented; and it serves as an useful aid to the latter, in assisting him to form an opinion with regard to the future state of the weather.

There are three theories respecting the cause of spontaneous evaporation, which at present divide the opinions of philosophers. In the first place, it has been long supposed, that the existence of vapour in the atmosphere arises in consequence of a power the air is said to possess of dissolving indefinite portions of water. Again, since the discovery of the general properties of heat by Dr Black, it has been imagined, that the evaporation of water exposed to the open air occurs in consequence of its combination with caloric, in a manner similar to that which is observed to take place in limited operations, by means of artificial heat. There are also some men, eminent for scientific knowledge, who ascribe the formation of vapour in the air to a peculiar combination of water with the electric fluid. We shall therefore subjoin a few observations on each of these opinions.

It has been ascertained, that water generally contains small quantities of air in solution. Dr

Priestley discovered it in the proportion of 1 to 30 parts of water; and he remarked, that air obtained from water by boiling or otherwise, is considerably purer than common air; and as water can be at all times recovered from the atmosphere, the opinion, that air and water have a mutual power of dissolving portions of each other, has been thereby supposed to be confirmed. At an early period of the last century, Dr Halley and M. Le Roi maintained an hypothesis respecting this question, which soon came to be generally embraced: they explained the existence of vapour in the atmosphere, as owing to a power possessed by the air of dissolving indefinite quantities of water, and which they supposed agrees in every respect with the nature of solutions in general; but the similarity of the process of spontaneous evaporation to that of any other case of chemical solution, will not admit of a strict comparison. Every solution has its precise state of saturation, but which is not possessed by the atmosphere in the present instance: it is likewise ascertained, that in every case of solution, by its decomposition, the substance dissolved is uniformly presented in the state in which it had existed previous to its combination. Air combines with water in the state of vapour only, from which it is uniformly precipitated in the liquid form, as in rain, or in the state of a solid, as in snow and hail.

Mr Dalton has shewn, that vapour possesses the same properties, when mixed with the atmosphere, as when in a free and uncombined state; and it is daily experienced, that the air, even highly impregnated with elastic vapour, answers the same purposes in the economy of nature as when in its driest condition. Were vapour raised and retained in the atmosphere, in consequence of its power of dissolving water, spontaneous evaporation must have increased, according to the gravity and density of the air, and would have therefore been most considerable in the polar regions, or upon the summits of our highest mountains, where this process is not counteracted by the effects of pressure. It has certainly been found, that water evaporates more readily at great heights; but this only happens when the temperature is raised artificially to the degree necessary to produce the same effect, in a similar portion of water, on a level with the ocean. Ice and snow have been found to decrease in bulk and weight, by evaporation,—a circumstance which does not seem easily accounted for by the above-mentioned theory; for, admitting that an affinity subsists between air and water, in its ordinary state, sufficient to enable the air to dissolve certain quantities of the water, it does not follow, that the same affinity should subsist under every change of this fluid. Water confined within the vacuum of an air-pump, is found to evaporate when exposed to the ordinary temperature of the atmosphere,—a circumstance which certainly does not admit of explanation by the theory suggested by Halley; and if it shall be afterwards found, that water evaporates more copiously in these circumstances, when the effects of pressure from the steam generated is guarded against, than an equal portion exposed at the same temperature to the open air, it will go far to disprove this theory entirely. The solvent powers of matters, in general, are increased by heat: at first sight the atmosphere seems to follow the same rule, in the process of evaporation, as water evaporates in greater proportion in warm latitudes, and during the warm season in temperate climates. Were the existence of vapour in the atmosphere owing to a solvent power of the air, it must have been raised in the form of water only. Vapour is a body possessing distinct properties, and totally dissimilar in its nature from what a solution of water in air would be. There is no fact in chemistry better ascertained, than that vapour, in every instance, owes its existence to the effects of caloric; and a considerable diminution of the temperatures of surrounding matters uniformly accompanies this process in every instance.

Although air is capable of holding indefinite portions of vapour, Saussure supposes this rarely exceeds a third or a fourth of the specific gravity of the air, being about 200 or 250 grains of water to a cubic foot,—a proportion nearly agreeing with the experiments of Mr Watt on this subject. Now, considering the great disproportion between the specific gravities of air and water, it seems impossible that even a much less proportion of the volume of the latter could be retained in the atmosphere, in consequence of the great increase of density it would occasion; and were the existence of vapour in the atmosphere depending on the solvent power of the latter, counteracting the aggregate attraction of the liquid particles of the water, no precipitation of rain, snow, or any watery meteor, could appear unless in a supersaturated state of the solution. It likewise appears difficult to conceive, how the atmosphere should possess the power of dissolving indefinite portions of water, and yet retain its elasticity, and even have its elastic powers thereby increased: considering the great difference between the degrees of density of these fluids, one would, *à priori*, imagine the solution should possess a gravity superior to the mean of both.

In Saussure's Essai sur l'Hygrometrie, p. 240, there is the relation of some experiments, by which it appears, that water evaporates in an equal quantity, when confined with a certain portion of common air, hydrogen or carbonic acid gases. The same fact has been more recently remarked by Clement and Des Ormes; and they afford a very conclusive proof against the supposed powers of the atmosphere for dissolving water. Were spontaneous evaporation owing to this property in air, we should naturally expect to find, that fluids differing so materially in point of density, would take up corresponding proportions of this liquid: but even the affinity subsisting between air and water, cannot be admitted as a proof of the solvent power of the atmosphere. We have a striking analogy of the contrary, in the instance of quick-lime and water: thus, lime has a very strong affinity for water, and combines with it in considerable proportion, without undergoing any change of its properties; nevertheless that substance is only soluble in water in a very sparing quantity. It has been already observed, that spontaneous evaporation goes on even when the atmosphere seems saturated with vapour, and likewise when it is actually in the state of devaporation: this is easily ascertained, by means of a sponge or piece of linen soaked in water, suspended to the end of a balance, and freely exposed to the open air, under a shed or at a window, when it will be perceived, that they readily lose weight, in consequence of the evaporation of water from their surfaces; and in this manner they will become dry even during the heaviest rains. Now, it can scarcely be supposed, that processes so different in their natures should take place in the atmosphere at the same time, and in consequence of its immediate influence. Besides, that the atmosphere does not possess the power of dissolving water, has been demostrated by Mariotte,—see p. 264. de ses Œuvres. By confining a quantity of air over water, he found, that after a certain period the air was considerably diminished in bulk, in consequence of a quantity of it having been dissolved in the liquid.

There is still too little known of the nature of the electric fluid, to enable us to speak decidedly of its effects in the process of evaporation. The following are the principal circumstances from which the opinion of its power in this respect has been assumed. A considerable proportion of electricity is at all times passing from the earth into the atmosphere, during evaporation. This fluid is likewise known to predominate in clouds, and the atmosphere itself is a powerful electric. But with all these facts in support of this opinion, it must be kept in remembrance, that the inference to be drawn from Dr Priestley's experiment, formerly mentioned, militates very strongly against the supposed evaporating power of electricity: and the same result has been confirmed by similar experiments performed by Van Marum; and those conducted by Saussure, afford the same inference. The electric fluid being possessed of the strongest repellent power, by uniting with vapour, either in its elastic or vesicular state, it may thereby increase its elasticity; but there does not exist any proof to shew, that vapour owes its formation to it alone. Indeed, from the observations of Saussure, we are rather inclined to suppose, that vapour is combined with a less proportion of electricity than water. From this cause we are unable to account for the cold which is always experienced during evaporation, or why the higher regions of the atmosphere should be more void of humidity, while a greater proportion of electricity abounds there than in the lower strata.

The effect of heat in causing the evaporation of water, has been already explained; and the same doctrine applies to this process, whether it occurs from the direct application of fire, or takes place spontaneously, when water is exposed to the open air. By this theory, the cold experienced in consequence of evaporation, is readily explained, and why the upper regions of the air are always drier, being of a lower temperature, than the strata nearer the earth. In consequence of the greater heat of countries within the tropics, and the higher temperature of summer in the temperate zone, evaporation goes on in those places more briskly; and during winter, every where, it suffers a corresponding diminution, owing to the diminished influence of the efficient cause.

De Luc is supposed to have been the first person who applied the doctrine of heat, in the evaporation of water, as having a similar effect in every circumstance, but which the illustrious discoverer of its general properties, seems evidently to have included in the lucid doctrine he gives in explanation of them. By this theory it is evident, that water can exist in the atmosphere in the state of vapour only; and that, therefore, the elasticity and specific gravity of the mixture of these two bodies, bear a proportion to the respective force of each individually: in this way it is understood, why the difference of elastic force between the vapour already in the air, and that rising from the surface, should have an influence in promoting or repressing this process. In like manner, we are enabled to account for the evaporation of ice and snow, which is likewise uniformly followed by a farther diminution of temperature: and the cause of the evaporation of water, when confined in a vacuum, is thus also satisfactorily explained.

Some of the most eminent chemists of modern times have imagined, that vapour exists in the atmosphere in the state of mechanical mixture: its particles being diffused through those of the air, in a manner similar to what happens in its mixture with any other heterogeneous fluid. De Luc, and Mr Dalton also, strenuously maintain this doctrine; and in favour of which, the latter philosopher has brought forward some very ingenious arguments. According to Mr Dalton's opinion, the pressure of the atmosphere has no effect either in promoting or in repressing the evaporation of water. He likewise supposes, that the particles of heterogeneous fluids, neither attract nor repel each other; consequently, that vapour ascends through the atmosphere, in proportion to its degree of elasticity, and is diffused through it, in consequence of the repulsion between its own particles. It has been already shewn, when treating of the gravity of the air, that the former of these propositions is not agreeable to actual observation, the weight of the circumambient air having a very considerable effect in varying the temperature at which liquids evaporate. There are also many facts which shew, that the particles of every gaseous matter, dissimilar in their natures, do not repel each other; on the contrary, in certain circumstances, the strongest degree of attraction subsists between many of them. This is exemplified in the combinations formed between aqueous vapour, and the vapours of several of the salts, as nitric acid, muriatic acid, ammonia, &c. Besides, there are several circumstances which directly shew, that an affinity, to a certain degree, does subsist between the particles of watery vapour and atmospheric air. This seems to be demonstrated by the transparency of vapoury air, and by the difficulty that is experienced in completely freeing a portion of the atmosphere from the whole vapour it contains. At the same time, it is to be observed, that when these fluids are united in certain proportions, the degree of affinity between them is not so forcible as to alter materially the properties of either. M. de Saussure is perhaps the first who maintained the opinion of the existence of vapour in the atmosphere, in a state of combination with it: and in support of this opinion, he has adduced some ingenious observations; but, for the following reasons, it does not appear, that these are combined intimately, unless when vapour exists in the air in small disproportionate quantities. In a vapoury atmosphere, its weight, and its increased elasticity, are probably always in proportion to the quantity and temperature of the vapour it contains. Besides, were vapour retained in the atmosphere in a state of intimate chemical union, its upper regions must have at all times been found fully impregnated with it, in consequence of the continual motion of the atmosphere, and its increased elasticity, when combined with vapour. As the vapour contained in the atmosphere is the source of rain and snow, &c. it does not readily appear, according to Saussure's opinion, by what power the disunion or condensation of the vapour could be effected in its higher regions, or by what particular cause, on the separation of vapour from the atmosphere, it should appear in a form different to that in which it existed in it. Upon the whole, it would appear, that similarly to what takes place in the affinity subsisting between many of the rarer fluids, in proportion to the dryness of the air, so much stronger is the force of the affinity subsisting between it and the vapour it contains: that this affinity gradually diminishes according to the proportions of vapour, which, probably, in frequent instances, is evolved in such over proportion, as to exist in consequence of its own elasticity alone, in which case its disunion and condensation must take place much more readily.

The celebrated Lavoisier seems to have originally entertained an opinion respecting the manner in which vapour is disposed of in the atmosphere, and which is totally different from either of the former theories. In explanation of this question, he imagined, that a considerable part of the vapour is completely decomposed, and reduced to its constituent principles, on mixing with the atmosphere; and in this manner, he considered the higher regions of the air as consisting of hydrogen gas only, and that, in these elevated regions, the luminous or fiery meteors had their origin from this cause. Dr Pratt and others enter keenly into this view, and many observations have been adduced as convincing proofs of its correctness. In this way, it has been likewise maintained, that as the proportion of water evaporated is commonly greater than what is devaporated as rain and other aqueous meteors, it should be held as a circumstance affording the strongest probability of the correctness of this hypothesis. However, this part of the argument will come to be considered afterwards, when an explanation of the circumstance will be given on more obvious principles. Indeed, the whole of this theory is built on conjecture alone. There is no proof existing to show, that the higher regions of the atmosphere consist of hydrogen gas ; and it has been thought to be inconsistent with the provident care of Supreme Wisdom, manifested in the economy of the universe, that a medium possessing the most inflammable nature should form any considerable portion of this fluid,

It has been found a subject of difficult investigation, to determine the quantity of water raised by evaporation from a given extent of surface within a given period: therefore, an approximation to the truth can only be expected. Much useful information has, however, been acquired by the industry and perseverance of many ingenious men, in the investigation of this matter.

The celebrated Dr Halley was perhaps the first person in this country who attended scientifically to this subject. By conclusions drawn from his experiments, it appears, that the annual evaporation from every square inch of surface is about 21 inches, being 6914 tons for every superficial mile. Dr Dobson of Liverpool, from a series of experiments continued during four years, computes the annual evaporation of water at 36.78 inches from an inch of the surface of the ocean. But, considering that the soil reflects the rays of the sun more powerfully than water; that it is more readily heated; and that the transpiration of vegetables must add to the quantity of evaporation; it appears, that in the day time the quantity evaporated from land will be fully as much as that which takes place from an equal extent of water. This seems agreeable to the result of some experiments performed at Bradford in New England, where the evaporation was found to amount to 42.65 inches in the course of the year. Dr Hales likewise found, that tracts of country covered with woods emit more vapour than an equal extent of ground covered with water; and during the space of nine hours in a day in winter, he even collected vapour that amounted to $\frac{1}{10}$ of an inch from a square inch of surface. However, it is probable, that the average amount from the whole extent of the ocean greatly exceeds in proportion either of these experiments. According to Abbé Richard, it has been calculated, that the annual evaporation from the ocean all over the world amounts to a quantity of water equal to 60 inches in thickness. In favour of this opinion, it is to be observed, that as the temperature of the atmosphere over the ocean is warmer and more uniform during winter, the quantity of vapour raised from it will be therefore more equable through every season and climate. The concentrated solution of salts and water do not evaporate so fast as pure water. Wallerius has shown, that evaporation from water containing 16 *per cent.* of salt, was nearly equal to that of simple water, after the salt was dissolved; but, during its solution, evaporation was diminished, from the cold produced: therefore, as the water of the ocean contains but little more saline matters than in these experiments, evaporation from it will be as great as that from lakes. Nevertheless, the vapour from the soil will be found to exceed in quantity that raised from the ocean in the torrid zone, in temperate climates, during warm weather, and in inland situations, where the vegetation is vigorous, and where the land is marshy, or intersected by lakes and rivers, which must participate in the heat of the soil, which is always much warmer than that of the ocean in such places. Mr Dalton ascertained, from a series of experiments, that in a situation pretty much exposed to wind and sun, the greatest daily evaporation, for thirteen days of March, was .064 of an inch; for twenty-one days in April, the greatest daily mean was .1115; for twenty-six days in May, the greatest mean was .1346; for fourteen days of June, the greatest .098; for fourteen days of July, the greatest .195; and he never found the evaporation from water any summer much to exceed .2 of an inch in twenty-four hours in the hottest weather; and from experiments still more recent than these, he supposes the mean evaporation over England for the year to amount to about 30 inches. Dr Watson has made a calculation of the quantity evaporated in a hot day in summer 1779, and when no rain had fallen for a month previously: he found, that 1600 gallons of water were raised in vapour from an acre of ground, in the course of twenty-four hours. Enormous as this proportion seems, it is still much less than the calculation above mentioned by Dr Dobson. The proportion of evaporation varying in the different months of the year, is in the following rate, according to his observations.

January,	1.50 inches.	July, -	5.11 inches.
February,	1.77	August,	5.01
March,	2.64	September,	3.18
April,	3.30	October,	2.51
May,	4.34	November,	1.51
June,	4.41	December,	1.49

The whole amounting to 37.48 inches.

A similar proportion must take place in the evaporation of water in every climate, unless within a few degrees of the equator; as there is not perhaps any country where that process goes on equally during the different seasons of the year. M. Cruquius has ascertained, that at Delft, the evaporation amounts only to 28 Paris inches annually; which nearly accords with the experiments of Mr Dalton in this country; though it has been found, by experiments during 1799, 1800, 1801, that the evaporation at Manchester amounted to 44.4 inches annually.

From the experiments we possess respecting the quantity of evaporation, no certain deduction can be inferred of its general proportion. The observations are neither sufficiently numerous, nor are the best conducted experiments on this subject susceptible of great accuracy; the results assumed from them being, in every instance, calculations from data afforded by trials on a limited scale; and it is known, that a liquid evaporates much faster, when confined within a small space, than when a great volume is exposed to the air. But evaporation must vary even in places situated near to each other: as, besides the influence of local situation, face of the country in respect to vegetation, plantations, lakes, &c. it must also bear some proportion to the quantity of dew, rain, and humidity arising from every other source. On account of the insular situation of Britain, it is therefore probable, that the mean evaporation from its surface, is greater than what the general calculations make it: perhaps that of Dr Dobson approaches nearest the quantity. It has been always a matter of considerable difficulty, to obtain a knowledge of the proportion of vapour existing in the atmosphere at one time; no means having yet been discovered, of extracting the whole which is contained in a given portion of it.

During warm weather, in temperate climates, and in the torrid zone, evaporation frequently goes on for several months, without any precipitation of water from the air, excepting what falls in the form of dew; and even then, the atmosphere does not appear saturated. At other times, even after the heaviest rain, its difference in this respect is scarcely indicated by the hygrometer. Owing to the currents of air blowing during a great part of the year from one point of the compass, in certain countries, the vapour raised from their surfaces is not returned to them in the form of rain, but is wafted to some distant situation: thus, it never rains in Lower Egypt, nor over a considerable part of the western coast of South America; and likewise in climates where the wind blows periodically, the evaporation continues while the current sets in from a certain point, without any intermediate fall of rain, but which immediately succeeds, when the air begins to take a contrary direction. Mr Clark, in his Letters on the Spanish Nation, mentions an instance where it did not rain in Castile for nineteen months; and even in the higher parts of India, it has been known not to rain for three years.

From the foregoing observations it will be manifest, that the atmosphere must contain a less quantity of vapour in proportion to its elevation above the surface of the earth; and as the lower stratum contains a greater proportion of this fluid, it is reasonable to suppose, that it is rarefied in a greater degree than at the height of a few thousand feet; the rarefaction of the different strata taking place in proportion to the quantity of vapour they contain, notwithstanding the pressure of the superincumbent regions. Vapour being more elastic than air, it will continue to ascend in the atmosphere, till by a loss of temperature, the density of the air in respect to it, becomes proportionally greater, its ascent being thereby gradually stopped: it then begins to assume the form of vesicular vapour, the specific gravity of which, although nearly equal to that of the atmosphere, is continually increasing in regard to this fluid, in consequence of having become more condensed, and proportionally less elastic, by its change from the elastic to the state of vesicular vapour. It therefore begins to descend, and uniting, form clouds, the farther condensation and immediate precipitation of which, is frequently prevented by the existence of a variety of causes. Vesicular vapour collected in masses, or otherwise, has a considerable attraction for the air in which it floats, and its rapid precipitation is resisted in a manner similar to what happens on the precipitation of any metallic solution. In this case, although the particles of the metal are of much greater specific gravity than the solvent, they descend very slowly, their motion becoming more rapid in their descent. The same thing probably occurs in the precipitation of condensed vapour through the atmosphere; and its descent and complete condensation is frequently opposed by the greater density of the lower stratum of air; while at other times, this occurrence seems to be prevented, in consequence of the continual elevation of vapour, in its most elastic state, from the surface of the earth, together with the tendency of the air upward, owing to the heat of the reflected solar rays. For these reasons, clouds are rarely seen to be formed in the highest regions of the atmosphere, except in very warm weather, or in the hottest climates, nor in the situations immediately over the earth's surface, except in sudden changes to very cold weather. Indeed, it is manifest, that the point at which vesicular vapour begins to collect into clouds, must vary with the climate and season of the year, being higher over warm latitudes, and in summer in temperate climates. This will appear more evident from the following table from Mr Dalton's Essays, being the result of observations taken by his friend Mr Crossthwaite.

	Clouds from 0 to 100 yards high.	From 100 to 200 yards high.	From 200 to 300 yards high.	From 300 to 400 yards high.	From 400 to 500 yards high.	From 500 to 600 yards high.	From 600 to 700 yards high.	From 700 to 800 yards high.	From 800 to 900 yards high.	From 900 to 1000 yards high	From 1000 to 1050 yards high.	Above 1050 yards high.	Number of observations.
Jan.	0	9	12	28	53	39	37	32	30	39	36	116	431
Feb.	5	10	5	15	41	45	45	27	43	38	29	94	397
March	2	1	6	11	22	40	32	36	24	32	44	184	434
April	0	4	5	18	24	34	27	26	23	38	35	206	450
May	0	1	4	8	13	31	22	25	30	34	27	270	465
June	0	2	2	6	24	24	29	21	34	41	34	233	450
July	0	2	2	18	35	36	35	25	35	48	38	191	465
August	0	4	5	13	27	39	35	26	25	45	30	215	464
Sept.	0	1	7	13	38	38	32	30	27	51	27	186	450
Oct.	2	0	5	13	26	49	31	31	46	61	37	164	465
Nov.	0	0	3	13	30	58	42	38	46	45	47	128	450
Dec.	1	8	6	23	41	53	39	50	47	46	35	111	460
Total,	10	42	62	179	374	486	416	367	410	518	419	2090	5381

Guy de Lussac perceived clouds floating at a considerable distance above him, when his balloon had reached the height of nearly 23,000 feet above the level of the sea; and Bouguer made a similar observation when on the summit of the Andes; he discovered clouds considerably elevated above the lower term of congelation. But M. de Saussure, in consequence of an experiment, imagines that vesicular vapour may even exist at the height of 13,500 toises above the earth's surface.

Mr Dalton does not suppose, "that the condensation of vapour exposed to the common air does in any manner depend upon the pressure of the air." This is an opinion that does not readily admit, either of confirmation, or of being refuted. But from what has been premised respecting the condition in which vapour exists in the atmosphere, it seems probable, that it will be condensed there by the operation of similar causes to those which convert it into water in other circumstances; therefore, when vapour has reached the higher regions of the air, which from the diminished temperature must be more dense than the portion immediately contiguous to the earth, the vapour must likewise suffer a diminution of its temperature, and, losing its elasticity in a corresponding degree, will have its density increased from the compression of the air, which, by its loss of temperature, it is less fitted to resist. It does not appear, however, that the effect of cold alone is sufficient to condense completely the vapour contained in the atmosphere; for were its condensation entirely owing to this cause, vesicular vapour would almost in every instance resume its more elastic form, in descending through the warmer strata of the air: it seems therefore more probable, that vapour, having to a certain degree lost its elastity, by being deprived of a portion of caloric, it suffers a more complete condensation than otherwise would occur, in consequence of the pressure of the superincumbent column, which likewise prevents it resuming the elastic form, in passing towards the earth's surface.

M. de Luc has observed, that clouds are formed in regions of the atmosphere, where the air is not indicated by the hygrometer as being saturated with moisture; but we have seen, by the experiments of Mr Dalton, that the condensation of vapour probably never occurs from this cause; nor is it necessary that it should be so in this instance: if vapour is condensible from the causes already mentioned, (diminished temperature and pressure,) these always exist in the regions where the clouds are formed, and must act on every portion of vapour exposed to their influence. The same philosopher likewise observed, that the temperature of the clouds themselves is greater than that of the surrounding air. This is what must naturally take place, from the conducting power of vesicular vapour for caloric being greater than that of atmospheric air: its temperature will therefore be higher, which will likewise be augmented by the gradual condensation of the vesicles forming the cloud.

There is evidently a very strong reciprocal attraction between the minute particles of vesicular vapour; and this attraction seems to be increased in proportion to the mass collected: it is frequently observed before the heaviest rains, that the formation of vesicular vapour rapidly increases by additions from every quarter. The collections of vapour possess a specific gravity the same as in smaller masses; but in respect to an equal volume of the medium in which it floats, it most probably varies according to its state of rarefaction and temperature. If vesicular vapour were more dense than the atmosphere, it must have been immediately precipitated on its formation; but being of nearly the same degree of density, its descent is opposed by whatever increases the density of the lower stratum: it is in this manner we suppose an explanation is afforded for the appearance of distinct and frequent masses of collected vapour being seen during the prevalence of a north or north-east wind; the stratum of air at the surface being more dense, of course it causes the vapour to remain in a region where the gravity is nearer equal to its own weight. Clouds sometimes remain buoyant in the atmosphere, until by accumulation the vesicles become so compressed, that the formation of rain immediately takes place. Dense clouds floating in this manner are often dissipated by the heat produced from the rays of the sun reflected from their upper surfaces; at other times, they remain permanent during day, and disappear in the night. This circumstance is most frequently perceived to occur in the atmosphere over islands, places on the sea-coast, and in mountainous countries, and is generally occasioned by what is termed the land breeze. Clouds that have remained in the atmosphere for some time, without shewing a tendency to a greater state of condensation, frequently dissolve in rain, by the sudden occurrence of a change in the density of the air itself. A cloudy sky, with a current of air from a certain quarter, will often continue for several days, when a sudden alteration in the course of the wind is immediately succeeded by rain.

In every country, particular winds are noted for being always accompanied by rain. South winds bring much moisture with them into Britain: indeed, our heaviest rains happen when the current of air blows strongly from that point. These winds being of an higher temperature, and proportionally impregnated with vapour, their condensation is therefore more sudden and forcible when they reach these latitudes, on account of the lower temperature of the climate: as they spread into the interior, their humidity is devaporated gradually in less proportion: it is from this circumstance, that on the west and south-west coasts of Britain, the quantity of rain that falls is greater than on the eastern coast or midland counties. A current of air from a southerly point of the compass generally impedes the rays of light from reaching the earth's surface, and the sky during its prevalence is not perceived to be covered with distinct clouds, as when the air blows from the west. The rain is therefore generally of longer continuance, and is diffused over a wider space.

The ascent of vapour through the atmosphere, in the manner pointed out, has been supposed not to be easily reconciled to the existence of different states of electricity in the various strata of that medium; for as vapour is an excellent conductor of electrical fire, by rising through the atmosphere, it is supposed that an equilibrium in the state of its electricity would be thereby restored, and of consequence the whole lower tract of the air must have speedily acquired an uniform condition of that fluid: neither could there be a variation in the electrical state of clouds differently situated, and of course no thunder storm could have ever occurred. But on considering what has been premised respecting the existence of electricity in the atmosphere, it must appear, that the ascent of vapour, so far from having a tendency to produce an equilibrium of that fluid in the air, will rather tend to induce variations of its quantity in its different strata. It has been already shewn, that owing to the difference of the temperature of the air in the night and day time, the quantity of evaporation likewise varies: thus, the evaporation being more copious through the day, a greater proportion of electricity will be then communicated to the air. The vapour raised in sunshine, owing to the diurnal variation of the temperature of the atmosphere over land and ocean, takes a direction more inland. Again, the vapour which is elevated during the absence of the sun's rays, is usually carried off in an opposite direction, by what has been called the land breeze; which follows the course of the former on the re-appearance of the sun upon the horizon, a contrary current similar to the first being then established. From this circumstance, there must be everywhere something like alternate portions of air differently charged with electricity; and it seems probable, that, in this way, the negative and positive states of its different strata are established.

The late ingenious Dr Hutton promulgated a theory of the cause of rain, which, as it is at present most generally followed, requires to be stated in this place. He supposes, that the immediate precipitation of rain is effected by the concurrence of opposite portions of air at different temperatures, and equally saturated with moisture. This opinion, however plausible it may appear, is liable to considerable objection: it is not easily to be conceived, how the meeting of any portions of the atmosphere should in this manner be capable of producing rain. The union of these portions of air, however different in temperature from each other, would not occasion any difference in the mean heat of the mixture; consequently the capacity for retaining vapour must remain the same, provided there be no remarkable difference in the quantity of the opposite masses of air. Indeed, though it appears evident that cold, and a corresponding density of the air, are causes which principally, if not entirely effect the condensation of vapour in the atmosphere; yet it does not readily appear, how the mixture of two different currents of air should produce this effect. Were this the real cause of rain, it is evident, that a diminution of the temperature of the air would always precede its fall. Before the precipitation of rain can take place, it is necessary, that vapour should previously assume the vesicular state: and yet, if in that condition rain be occasioned by the meeting of opposite currents of air, it may with greater probability be imputed to the effects of compression than to any other cause: Moreover, it appears, that were Dr Hutton's opinion on this subject correct, the greatest rains in Britain should always follow a north wind, it being colder and more dense than that from any other point; and the atmosphere over the island is at all times sufficiently impregnated with vapour to afford rain: indeed, according to this theory, rain ought to take place on every variation of temperature, or change of the current of air.

Dr Kirwan imagines, that the immediate cause of rain is in consequence of the subtraction of the electric fluid, which keeps the particles of vapour at a distance from each other. This most frequently happens from the repulsion or attraction of other clouds; thence ensues an increased volume of these particles, which, by collecting, form drops, whose weight being superior to the resistance of the air, they necessarily descend, and form rain. That an alteration of the electrical state of the atmosphere arises during the evaporation of water, has been already mentioned; and, no doubt, a corresponding variation will ensue when this vapour is condensed; but how far it can be considered as the immediate cause of rain, it is impossible to say in our present state of knowledge: but, on taking a review of these processes, it rather appears, that the changes of the electrical condition of the air while they take place, arise in consequence of the change of form in the water, and are not to be considered as the immediate cause of either. It appears, that rain uniformly takes place in every circumstance, whenever the increasing pressure of the superincumbent air exceeds in a certain degree the resistance opposed to the condensation of the clouds, by the ascent of the vapour and air from the surface; or by the density of its lower stratum. It is in this way, we find, that it rains oftener during night; and when this resistance is subverted in the day-time, the rain that falls is generally heavier and of longer continuance. The same doctrine is also applicable to what is observed of the quantity of rain which falls in different climates through the different seasons. This occurrence most probably arises from such causes as obstruct the passage of the sun's rays to the earth, and whatever impedes the evaporation of water, as a cloudy atmosphere, the absence of the solar rays during night, or in winter in temperate climates. The operation of the former seems frequently to have the effect of occasioning rains, in intertropical countries, during the prevalence of certain winds. By this doctrine also, we understand why the number of rainy days increases in latitudes receding from the equator; and likewise, why the quantity of water which falls in rain is much greater in warm climates, and in temperate latitudes during summer.

The drops of rain have been always found larger the lower in the atmosphere. The late Dr Walker experienced, on descending a high mountain, that the drops increased in size as he approached the bottom. At a little way below the summit, the precipitation seemed only a gentle mist, which gradually became more dense as he descended, and, on reaching the valley, it had increased to a very heavy rain. This happens in consequence of the coalition of the particles of condensed vapour, which is probably in a great measure occasioned by the increasing gravity of the air in descending.

The above circumstance has been likewise confirmed by experiments of the Bishop of Llandaff; though Mr Copland of Dumfries seems to have occasionally perceived, that more rain fell in a rain-gauge elevated to a certain height in the atmosphere, than in one placed on the earth's surface. He observed likewise, that when the quantity collected in the lower gauge was greatest, the rain was always of longer continuance. This appearance is not easily accounted for, and very probably depends on some circumstances connected with the place where the experiment was conducted. It disagrees with common observation, and is expressly different from the results afforded by other experiments performed in the most accurate manner in different situations. In the years 1776 and 1777, Dr Heberden ascertained the proportions of the quantity of rain that fell in three rain-gauges, placed at different heights in the air: one of them was placed on the ground; the second was fixed on the top of his own house; and the third was situated on the highest tower of Westminster Abbey, all in the immediate vicinity of each other. In the first gauge was received 22.608 inches of rain; in the second, 18.139 inches, and in the highest only 12.009 inches. Mr Daines Barington conducted some experiments also which lead to the same conclusion. They were performed on a very high hill in Wales, at a distance from any town; and he found, that there was always half an inch more rain in the gauge on a level with the sea, than in the other, 1000 feet high on the mountain. The smaller drops of rain uniting as they descend, become larger the greater distance they have to fall. It is from this cause, that showers in summer are more heavy, for the time they last, than at any other season of the year. It has been formerly mentioned, that marshy and maritime situations emit a greater quantity of vapour: these are likewise observed to be more rainy. This is also experienced to occur in mountainous countries. Hills are often observed to have their summits covered with rain or heavy dew, while the air remains quite dry in the valleys. Thus, it has been remarked, that on the Andes it rains constantly, and often descends on Quito in prodigious showers, while in Peru this circumstance rarely occurs. The cause of this has been imputed to a supposed attraction between the clouds and high grounds of the interior; and electricity has been supposed to be the intermediate agent. But, even on this supposition, the difficulty is not cleared up. It seems, with more probability, to be owing to the cold and dense state of the atmosphere in higher situations, which, by completely condensing the masses of vesicular vapour that are conducted into the interior by the diurnal breeze, are thus stopped by the most sed on the subject, and affords a fact which militates strongly against the theory of Dr Hutton; as, according to his opinion, night should have been more wet than day, and the coldest climates must have had the greatest quantity of rain. M. Toaldo concludes, from long observation, that in spring it rains oftener in the evenings than the mornings; but towards the end of summer and in autumn, it rains oftenest in the mornings, and then also storms most frequently happen at a little past sun-rise. He also found, that rains occur most frequently at the points corresponding to the quotidian angles of the moon, and that rain happens oftener at the perigean, and the full and new moon, than at the apogean or quarters.

The quantity of rain which falls in the different regions of the earth, varies as much as the proportion of evaporation; nor has this particular circumstance been more accurately ascertained. Within the tropics, where the rain falls in regular seasons, it is found to be much more copious than in those countries where it falls variably. At Bombay, during a south-east monsoon, from 15th May to 18th October 1790, 110 inches of rain have been known to fall, which is perhaps much less than the quantity which is devaporated nearer the equator. In Madeira, the quantity of rain that falls varies from 22 to 49 inches; at Charleston, South Carolina, it has been frequently found to amount to 56 inches during the year; at Grenada, even 126 inches have been precipitated; Cape François in St Domingo, 120 to 260; Calcutta 81; Rome 39. The country around Paris, or what is called the Isle of France, is perhaps the driest spot in Europe; the fall of rain there for the year, varying from 14 to 23 inches:

In Essex, it varies from	15 to 26 inches.
Northamptonshire,	17 to 27
Manchester, -	25
Townly, Lancashire,	39 to 41
Dover, - -	37.52
Ware, Hertfordshire,	23.6
London, - -	22.608
Kimbolton, -	23.9
Lyndon, - -	22.210
Chetsworth, -	27.865
Liverpool, - -	44.41
Lancaster, -	40.3
Bradford, New England,	31.4
Kendal, - -	64.5
Keswick, -	68.5
Upminster, - -	19.4
Berlin, - -	19½
Lyons, - -	37
Padua, -	37½
Pisa, - -	34¼
Udina, in Italy, -	56

There falls less rain in Berwickshire and East Lothian, than in any other county in Scotland.

At Dunse the annual depth is only	26 inches.
Glasgow, - -	31
Dumfries, - -	36.727
Langholm, - -	36.73
Braxholm, - -	31.26
Hawkhill, - -	28.966

At Petersburgh there falls but sixteen inches of rain annually; and the mean quantity of rain in England during the year, has been calculated at 32 inches; but it appears that this sum is much underrated. Mr Dalton has found, that both in Kendal and Keswick the mean quantity of rain has even sometimes amounted to 84 inches in the course of the year, and, from general observations, he makes the whole amount over England to be 36 inches, including five inches of dew. This nearly agrees with the calculation of Dr Dobson, who made it 36.78 inches. Pere Cotte has calculated, from data afforded by numerous experiments, undertaken in different places, and conducted with as much accuracy as the nature of the subject will admit, that the mean yearly quantity of rain which falls between 10° and 60° N. lat. amounts to 34.7 inches: this he insinuates may be pretty near that of the mean annual quantity over the globe; but from the proportions which fall in different places, as stated above, we should suppose this calculation is much under the real general quantity of rain.

The vesicular vapour contained in the lower stratum of the atmosphere, is frequently precipitated during the absence of the sun from the horizon; and it then sometimes appears as a rare uniform cloud, floating over the earth's surface, which resumes the state of water on coming into contact with the ground, whose temperature, as has been shewn, is lower in that season. This moisture remains on the leaves of plants, and on other parts of the surface of the earth, and is denominated dew, fog, mist, haze, &c. according to the abundance and celerity of its precipitation. This is ascertained to be a slow condensation of vesicular vapour, in consequence of the temperature of the air becoming gradually more cool, as the sun declines from the horizon. This opinion of the nature of this precipitation, is confirmed, by finding that dew falls but sparingly at sea, and is most copious at a little before sun-rise, and after sun-set. Dews are rarest about midsummer, the earth being then more arid, and its temperature greater as well as that of the atmosphere. No dew ever falls in the sandy deserts of Africa: it is most copious in calm weather, when the evenings are cool, having been preceded by a warm day, the wind blowing gently from the south or south-west; but there falls no dew when the north wind prevails. Dew is also most abundant in insular situations, sea-coasts, and in the vicinity of marshes. In several countries, the fall of dew is so copious and regular, that it seems to supply the want of rain, as in Lower Egypt, Lima, the coast of Arica, &c. &c. Dew falls more plentifully on meadow grounds than on ploughed lands; and it is supposed to have a greater attraction for animal and vegetable surfaces, for crude fossils, china, glass, and silk; and that it is repelled by all polished metals, but is attracted by them when covered with rust: it is supposed to be deposited copiously on ideo-electrics, but not on conductors. Muschenbroeck supposes, that it is likewise influenced even by the colour of matters, having a greater affinity to substances of a bright colour, than such as are of a deeper shade. In every country the low grounds are most covered with it, nor does it seem to reach to heights of even a few feet elevation. Volney found, that the high grounds of Syria were frequently free from dew, when the low situations were most plentifully covered with it. Hoar frost agrees in many of these particulars with the formation of dew, and seems only to differ by appearing in a very low temperature of the air. Dew only remains on the ground till the force of the sun's rays is sufficient to cause its evaporation: for this reason, it is never seen to remain through the day; and it is always most remarkable about sun-rise and sun-set, there being the greatest difference at both those seasons between the heat of the earth and atmosphere. The formation of dew has been very generally imputed to electricity, chiefly because it seems to have a predilection to settle on sharp points; and M. Achard, in the Berlin Memoirs, taking notice of this circumstance, mentions, that a sudden overcasting of serene weather, indicated variations of the electricity of the lower air. It was the opinion of M. Le Roi, and other celebrated naturalists, that dew was not always produced from the air, but that it frequently appeared in consequence of exhalations from the earth, and also from growing plants. Muschenbroeck confined its origin to these two last sources, and he imagined this opinion was confirmed by observing, that dew falls rarely on elevated grounds, and that it never reaches the tops of buildings; and also, by finding that dew is frequently perceived to possess peculiar properties. In opposition to this opinion, M. Ek very justly observes, that were dew entirely owing to exhalations from the soil and plants, we should find some moisture adhering to the under surfaces of the leaves of vegetables, which is never perceived; and that plants would be thereby lighter in the morning, which is contrary to his experience. Pere Cotte found, by covering up an artichoke under a bell glass, that the surfaces of its leaves were covered with dew; but this most probably took place in consequence of the condensation of its own exhalation.

The water of which dew is formed, has been found to possess properties different from rain water in general, and even to vary in its nature. It has been said that dew corrupts sooner, and that it contains a greater proportion of oxygen gas than rain; others affirm, that even a spirit has been extracted from it by distillation. Borelli asserts, that in some instances dew has been found capable of dissolving gold. Michael found some that contained a portion of muriatic acid; and Digby imagined he had discovered nitric acid in some dew water he analyzed. The dew of some countries contains more heterogeneous matters in it, than that which is found in other climates, and is thereby extremely pernicious to health. Thus, the devaporation, in form of dew, that takes place in the evenings all over Batavia, in the West Indies in general, and other tropical countries, in the Campagna of Rome, vicinity of Naples, in Hungary, &c. generally produces diseases in those much exposed to it, and especially if a person falls asleep in the open air while it is separating. De Tott also mentions, that in the island of Crete the bay laurel sheds its effluvia so far around, as frequently to destroy those who unwarily fall asleep under its shade. The pernicious effects of the vapour exhaled from the boa-uppas tree, is likewise well known to the inhabitants of Java. The heavy dews which fall in Egypt have likewise been assigned, by every writer on the climate and diseases of that country, as a chief cause of the ophthalmia, which is so frequent amongst its inhabitants.

From the causes already pointed out, which are supposed to produce the matters which compose dew, it is found, that in many instances, this liquid must necessarily be impregnated with the more volatile and soluble matters of the soil, as well as the exhalations from plants; and as this species of devaporation always consists of what has been most recently evaporated, we are thereby better able to account for the variety of heterogeneous matters that are occasionally discovered in it. Its general composition, according to Pere Cotte, is, 1*st*, Water; 2*dly*, A greater proportion of earth than what is found in rain water; 3*dly*, Muriatic and nitric acids; 4*thly*, A kind of unctuous earth left by its evaporation. We may therefore conclude with M. Ek and others, that dew appears in consequence of the decreasing temperature of the air, in the evenings, nearest the earth's surface: the vapour and exhalations, which had been previously elevated by the force of the sun's heat during his continuance upon the horizon, then begin to assume the liquid form, the declining temperature of the air being insufficient to retain them in their elastic state. Dew being moisture devaporated from the stratum of air nearest the earth's surface, affords an explanation why it is never discovered on elevated situations, and why its properties should be occasionally so various.

When the transparency of the atmosphere is completely obscured, during the precipitation of humidity in the form of dew, it is more usually denominated fog or mist; and this term is applied to denominate the same circumstance, whether it occurs during day or in the evening. This meteor is likewise divided into marine and terrestrial fogs, according to the nature of the medium over which it hangs. Fogs never rise high in the atmosphere. The late Dr Darwin gives an account of one which overspread a tract of ground through which he had occasion to ride. He experienced, that on every rising ground he was quite above its level, and then the sky appeared distinct and clear; though, in the low ground, the haze was so thick, that he could scarcely discern the length of a yard beyond his horse's head. North-east winds very often conduct such mists into Britain. During the time these most commonly prevail in Europe, the temperature of the ocean over which they blow being at that season greater than the adjacent lands, is continually covered with a haze or fog: it is therefore in consequence of a quantity of this vapour being driven forward by the particular current of air, that we owe its appearance in this island. But a similar exhalation often arises during winter from the seas, lakes, and large rivers in the more temperate climates.

Fogs which appear during day, have been supposed to arise from the ground over which they spread, and ought not to be considered as a deposition of humidity from the lower stratum of the air. When terrestrial fogs appear, they are regarded as prognosticating dry weather. They are generally very unhealthful, especially in climates where the diurnal heat is great. Marine fogs are attended with no other bad effects to the health, than what arise from the damp they leave upon the surface.

There was a remarkable fog which spread over the whole of Europe, and part of Asia and America, for some months in summer 1783. It was perfectly dry, and did not deposite humidity. During its continuance, the electricity of the air was increased, and there happened a great deal of thunder and lightning. At that time, Mount Hecla in Iceland was in a state of eruption; and it is imagined, that it had its origin from that source. Terrestrial fogs generally originate from similar sources as those of dew; the air at such times being more impregnated with vapour, and the causes of devaporation being more forcible in their operations. But, besides the sources we have already mentioned, fogs likewise occur from the spray formed by extensive water-falls: that occasioned by the cataract of the Niagara is said to spread to the distance of two miles. But perhaps the most beautiful meteor of this description is that formed by the river Velino at Ternia in Umbria. This river takes its rise from the lake Di Luco, and has a very rapid course till it reaches the extremity of the hill Del Marmore, whence it dashes over a precipice of more than 200 feet, and with such rapidity and force, that it is at all times surrounded with what the natives call "un polverina d'acqua," which even rises several feet above the mountain's top, and is so thick as to obstruct the rays of the sun.

Snow and ice, we have already seen, are only varieties of the same change produced in water in consequence of the deprivation of caloric. It cannot therefore be doubted, that snow has its origin from the vapour mixed with the air; and that the peculiarity of its form and appearance is merely owing to the extreme tenuity of the vapour from which it is condensed, and to the low temperature of the medium where it is formed. It is the temperature of the atmosphere which is evidently the cause of the immediate production of snow; as it only occurs when the air contains a considerable quantity of vapour, and its temperature is reduced to the freezing degree. Snow was formed in the atmosphere of a crowded assembly-room at Petersburgh, by a stream of cold air having been admitted into the apartment through a broken pane of glass. It has been seen to be formed in similar circumstances by Pallas, Chappe, and others who have wintered in Siberia; and by the narrative of those Dutchmen who wintered in Nova Zembla, we are informed, that a fall of snow, from the vapour of expiration, occurred every time there was any communication with the external air. Snow is perhaps never formed high in the atmosphere; on the contrary, it seems only to appear when the point of congelation in the air is nearest the earth's surface, and when the lower stratum of the atmosphere is much loaded with vapour. Its peculiar appearance seems likewise to show, that cold occasions its congelation before the vesicular vapour has time to collect into clouds, and immediately on its conversion from the elastic state.

Hail very rarely appears beyond the 60° of N. lat. It occurs frequently in the warmest climates, and in temperate latitudes during summer. Thus, it very rarely hails in St Petersburgh; but it is frequently met with in Egypt, and in climates even under the equator. It sometimes occurs in winter after considerable falls of snow; and its appearance in summer is generally followed by a thunder storm, which is frequently succeeded by a milder temperature of the air. Hail is almost always of a round or oval figure; and it varies in magnitude, from a very minute size to that of a pigeon's egg, or even larger, its size being always smaller in the more northern climates: the larger size is most frequently experienced in the south of Europe, where its effects are most dreadfully destructive.

Hail has nevertheless been frequently experienced of a large size, of an angular or irregular shape; and then it is frequently mixed with small animals, bits of straw, wood, and earth: but in these circumstances, it is more reasonable to presume, that such matters have been previously elevated from the earth's surface by the operation of a whirlwind, or some similar meteor. Says the ingenious and accurate Volney, in his View of the Climate, &c. of America, "I had long refused to credit the existence of those hailstones said to weigh ounces, and even pounds, of which newspapers and travellers too frequently speak. But the storm of the 13th of July 1788 affords me the conviction of my own senses. I was at Ponchartrain, ten miles from Versailles, and going to see a sheep-walk at six o'clock in the morning, I found the rays of the sun intolerably scorching: the air was calm and suffocating; that is, it was extremely rarefied: the sky was without a cloud; yet I heard four or five claps of thunder: about a quarter after seven, a cloud appeared in the south-west, and then a very brisk wind arose. In a few minutes, the cloud filled the horizon, and speeded toward the zenith with an increase of the wind; and a hail-storm suddenly came on; the stones not falling perpendicularly, but obliquely, as at an angle of 45°, and so large, that you would have taken them for pieces of mortar from a roof falling down. I could not believe my own eyes: many of the stones were larger than a man's fist; and I observed, too, that several of these were only fragments of larger pieces. When I could safely venture my hand out of the door of the house to which I had very opportunely retired for shelter, I took up one, and found it to weigh more than five ounces by a common pair of scales. Its shape was very irregular, and it had three principal horns, as big as the thumb, and almost as long, projecting from the nucleus on which they were collected. I have been credibly informed, that a hailstone at St Germaines weighed more than three pounds: and after this, I know not what surpasses belief." I have preferred giving the above quotation from the works of one of the most eminent philosophers of the present day, rather than to refer to the writings of others, where similar facts are so apt to be embellished by prejudice and love of the marvellous.

The formation of hail has been supposed by Beccaria and others to be occasioned by the influence of electricity, and that it must therefore have its origin in the very higher regions of the atmosphere; but whether or not the formation of this meteor be owing to the power of that fluid, it will be generally agreed, that its origin takes place in the very elevated tracts of the air; but neither the peculiar figure of hailstones, nor the thunder storms that generally accompany their appearance, will warrant a conclusion for the proof of the above theory *in toto.* Muschenbroeck, whose judgment and accuracy of observation were of the first rate, found, that every hailstone contains as it were a nucleus, which is much harder than the outer layer; and he imagined, that this nucleus acquires its external softer covering by passing through strata of air loaded with vapour, which it condenses, and freezes in its descent. By passing through different strata of the air, it may be reasonably supposed, that a communication, and consequent equilibrium in their different conditions of electricity will thereby ensue, which will consequently give occasion to the thunder storm that usually succeeds. The opinion of Muschenbroeck is better suited to explain the appearance of hail, in certain latitudes and seasons; and the examination of a large hailstone will convince any one of the accuracy of his observation.

Hail is probably formed even above the lower term of congelation in the air; as it would appear, that in the formation of that substance, the condensation of vapour, and its immediate congelation, must rapidly succeed each other: its greater specific gravity will then cause its immediate descent, and in its passage it will acquire its peculiar form. In this way, we are enabled to account for the appearance of hail in the warmer regions of the earth, and during summer in temperate climates: this likewise affords a reason, why in these circumstances its size is larger. Snow itself, most probably, would appear always as hail, were it formed equally high in the atmosphere: the delicate texture in which it appears, would necessarily assume a round compact figure in its descent, in consequence of the compression of the air. Mr Dalton supposes, that the formation of hail may be occasioned by vapour already condensed, passing through a stratum of air cooled below the freezing point: though it is impossible to deny, that this may not sometimes take place, yet the observations of Muschenbroeck seem to be more satisfactory in explaining the circumstances connected with the most common appearances of this meteor.

Water-spouts are observed to occur both at land and at sea: some countries are more harassed with them than others; but their appearance varies according to the medium on which they are placed. Thus, in this species of meteor which occurs at sea, the waters seem to ascend into the atmosphere, while those met with at land, are characterized by a sudden discharge of an immense quantity of water upon the surface. Water-spouts have received different appellations according to their appearances: but, though they seem to disagree in their phenomena, they come to be treated of under the same head; the one being probably at all times the forerunner of the other. Water-spouts, whether of the ascending or descending kind, are always accompanied with storms of wind and thunder: these storms are supposed to attend most frequently those water-spouts usually met with at sea. Both species of water-spout are most common within the tropics, though probably no climate is exempt from them. Such as have the water elevated from the surface into the atmosphere, are frequent on the coast of Africa, where they appear in considerable numbers at a time, and are said to occur oftenest about the rising or setting sun, and about the equinoctial periods, rather than at any other season of the year. They evidently happen most frequently in those latitudes, where the temperature of the air and the evaporation from the surface are greatest.

The water-spout, denominated typhon, or syphon, when the water ascends from the surface of the ocean, is a meteor extremely dangerous at sea: ships are said to have been drawn within its vortex, raised to a considerable height, and then dashed into the ocean. Vessels often founder by these spouts breaking over them. Dampier relates an instance having occurred, where, although the sails had been previously furled, and every arrangement made to prevent any disaster, yet, by the force of the water falling upon the deck, the masts were broken off, and the ship otherwise so shattered, that she was rendered a complete wreck.

This meteor is always seen to commence immediately under a very dark cloud, which appears to hang unusually low in the atmosphere, declining considerably downward with one of its edges: at other times, it has an elongation from the most dense part toward the water; the sea is then perceived to boil violently below, and over a space corresponding to the volume of the cloud; a loud uniform rumbling noise is heard in the superincumbent atmosphere, while, at the same time, a column of dense vapour appears to ascend, which, uniting with the pendulous portion of the cloud, renders it still more dense and dark: the appearance which the water-spout then assumes, bears a considerable resemblance to the figure of a speaking trumpet; the mouth being represented by its junction with the cloud, the column tapering gradually to the surface of the water, where it is narrowest: at other times its figure represents the form of two speaking-trumpets, joined at their smallest extremities, which correspond to the middle of the column. This kind of water-spout is not always stationary, but moves about with the current of the wind. The pillar has been supposed to be hollow, and that the vapour ascends on the outside of a cylindrical tube, the rays of light having been observed shining through it; but an appearance of this kind leads frequently to deception ; it therefore cannot be admitted as an absolute proof of the existence of an internal cavity in the column. Their duration lasts from the space of a few minutes, to an hour or two. The circumference of the column is from the size of a foot, to that of 40, 50, or even 100 feet. This species of water-spout is not confined to the sea alone; there was one observed some years ago in the Lake of Geneva, which continued several minutes. The ascending water-spout continues most commonly till the cloud becomes too forcibly impregnated with vapour; the superfluous water contained in the cylinder is then precipitated with an immense crash ; lightning, together with thunder, and a strong wind whirling in all directions, accompany this mode of termination. At other times it dissipates calmly; the sky clears up, the cloud having dispersed through it, while the surface of the ocean becomes smooth and clear. Sailors usually cause them to disperse, by firing a shot at the cylinder; as they break by whatever interrupts the communication between the cloud and the ocean. Various hypotheses have been adduced in explanation of this meteor; but Dr Franklin, Brisson, and Beccaria, have brought forward the most plausible arguments in proof of its electrical origin. This opinion seems probable, from many circumstances connected with the phenomenon in question : it appears in countries where electric meteors in general are most frequent: lightning is also commonly perceived darting through the cloud with which the column is united; and it is likewise seen to play around the cylinder or cataract itself. Water-spouts are also known to have been dispersed, by presenting a sharp-pointed knife, or other piece of metal, which probably acts by giving the electrical fluid a different course. Beccaria and others have found, that the electricity of the atmosphere is considerably influenced by the appearance of dark clouds upon the horizon, and a similar cloud always appears at the commencement of the ascending water-spout. Neither are we acquainted with any other power that could produce so strong an attraction between a cloud and water, as to cause it ascend in opposition to its own gravity, and that of the superincumbent atmosphere. Abbé Richard, however, endeavours to prove, that this species of water-spout is produced in consequence of the collision of opposite currents in the air, which, by causing a kind of eddy, the water is in this manner forced upward. That eddies are formed in the atmosphere occasionally, will be readily allowed; but unless these have the power of producing a vacuum in the atmosphere, it is impossible that vapour could ascend in it, in a manner equal to constitute this meteor. Count de Buffon, to get rid of this difficulty, assumes some principles still more fanciful and gratuitous, in explaining the cause of this meteor. He thinks there is a central fire in the earth, composed of sulphureous, bituminous, and mineral matters, and that the extrication of air from these inflamed substances, finding an easier outlet under the ocean, gives occasion to this meteor, by forcing the water up before it. M. Brisson, and afterwards Beccaria, conducted an experiment by means of an electrical apparatus, which, although it may not be regarded as a decisive proof that electricity is the occasion of water-spouts, it will nevertheless be considered as giving corroboration to an opinion, which affords a more satisfactory explanation of this phenomenon, than any other hypothesis that has yet been advanced on the subject. He supported a drop of water from the prime conductor of his electrical apparatus, by means of a pointed wire, and, placing it over a vessel of water, all the appearances of an ascending water-spout immediately succeeded, except the previous appearance of vapour: the reason why this did not become visible, was, he thinks, owing to the want of power in the electrical machine. Now, in consequence of the variations of electricity in the clouds at different times, and which give occasion to thunder storms, when an equilibrium of that fluid is re-established, it can be readily supposed, that a considerable mass of vapour, which at all times abounds with electricity, may be so positively charged with that fluid, as to render its attraction for water sufficient to overcome the resistance to its ascent. In this way the water, in the form of vapour, will ascend into the cloud with increased velocity, owing to the increasing pressure of the atmosphere around the base of the electric attraction on its surface. The phenomenon will therefore continue, either till the electricity is lessened, by being communicated to an additional quantity of matter, or till the water that ascends is in too great quantity to be supported in the atmosphere; or till the process is interrupted by some other adventitious occurrence. The electrical origin of this species of water-spout is rendered still more probable by reflecting, that in consequence of evaporation the surface of the ocean must be continually giving off electricity; and during day it is perhaps commonly in a negative state.

The next species of water-spout we have to consider, is probably that meteor distinguished by ancient writers by the name of Dipsides, and which was long ago remarked as being prevalent among the Grecian isles. This, like the former meteor, is observed to occur more frequently in climates where the evaporation is great, though it occasionally appears in a less degree in every region. Perhaps as accurate a description of this meteor as any recorded, is of one that fell on the confines of Burgundy, May 28. 1741, and which is related in the works of

Abbé Richard, who was a witness of the circumstances. "At four o'clock in the afternoon, the wind being south, the air warm, and the atmosphere overspread with thick black clouds, collected by the winds over an elevated ground covered with wood on the north-west; thunder was heard from this quarter: and after a report of thunder more violent than the others, there scarcely fell a few heavy drops of rain toward the south, at the distance of half a league from the place over which the clouds appeared stationary. But an hour after, a valley, through which a rivulet run, that usually contained about the depth of six inches of water, and about a foot in breadth, was wholly filled with water, to the extent of 60 toises, and of a depth from 12 to 15 feet. This inundation was occasioned by the falling of a water-spout, at a short half league distant to the north on the rising ground. There it had fallen with such violence, that trees were torn up by the roots; whole flocks, with their shepherds, and even their dogs, were drowned; and all this happened on a height, where naturally they could not have expected such an occurrence. The fall of the water upon the declivity had been so great, that the trees and bushes were in a manner crushed to pieces by it. On the height of the mountain the rain had been very slight; but all the soil over its side, and a quantity of the trees, were carried down into the valley."

This meteor is generally preceded by a very loud noise in the air, different from that of thunder, and commences previous to the appearance of lightning: this has been supposed to originate in consequence of the tendency of the atmosphere to regain its equilibrium, and that the agitation and friction of the air from that cause, give occasion to the subsequent electrical phenomena. Indeed, the circumstances connected with the descending water-spout, have been also attempted to be explained on electrical principles, and in the same manner as thunder storms are produced. Thus, different strata of air, containing clouds differently charged with electricity, will always have the vapour of which they are formed condensed and precipitated, by the intervention of whatever causes an uniformity in their electrical states. The stratum containing the vapour elevated during the day, will not only be more saturated with it, but must likewise contain a greater proportion of electricity, than the stratum in which the vapour elevated over night is suspended. The former will therefore press downward as soon as its elastic vapour is condensed into the vesicular state, and it will descend still lower in proportion to the difference of temperature in the air between night and day: it is prevented from uniting with the substratum, by their difference in point of electricity; and its condensation is likewise resisted by the more elastic state of the vapour in the latter: but when this resistance is overcome, or when circumstances occur to render their electrical states uniform, appearances succeed, which, according to their magnitude, are either called a thunder storm, or a water-spout. But although it be admitted, that electricity is a common agent in occasioning this meteor, it has however been perceived, that this also takes place when electrical appearances seem rather adventitious than as giving origin to the phenomenon. Every atom of matter in the vast space of the atmosphere reciprocally compresses each other; this gives occasion to many important phenomena; and it is by this effect, causing a difference of gravity in the strata of the air, that Volney supposes water-spouts are occasionally produced. But, supposing that the ascending water-spout is occasionally the cause of the species now under consideration, by a precipitation of the vapour that had been elevated by it from the surface of the ocean, the influence of electricity must also be admitted as sometimes producing this effect: thus, supposing the dense cloud occasioned by the ascending water-spout to be in a positive state of electricity; from its great density and weight it will hang low in the atmosphere, and should it descend within the distance where it may be attracted by bodies in an opposite state of electricity, as hills, tall trees, forests, &c. the usual appearances must immediately follow,—an immense discharge of water, accompanied by thunder and lightning.

Having delivered a general account of evaporation from the earth's surface, and the manner how this vapour is again returned, before dismissing the subject it may be interesting to mention some circumstances regarding the proportions which rain and vapour bear to each other. It has been already mentioned, that in some local situations, the fall of rain exceeds the quantity of water raised in vapour. But the calculation of the proportion of evaporation over the whole globe, as determined by Abbé Richard, exceeds considerably the general quantity of rain as supposed by Pere Cotte. For reasons already mentioned, it seems impossible to ascertain accurately the quantity of either; but it has been supposed, that the evaporation of water considerably exceeds that which is dissolved in the form of rain, snow, or by aqueous meteors in general. This opinion is in some degree confirmed by the observations of M. Hassenfratz on this subject: nevertheless, for reasons which immediately follow, it does not appear that the general proportion of evaporation is much greater than the quantity of rain which falls over the different regions of the earth. It is observed, that the quantity of evaporation both from land and water, in the frigid and temperate zones, is not equal to the quantity of rain that falls there, otherwise there could be no rivers; and in proof of this opinion, we are supported by Mr Macgowan's experiments; the evaporation of water for the space of five years having been found to be much less than the quantity of rain in the vicinity of Edinburgh. On the other hand, it seems probable, on considering the great quantity of vapour which is raised within the tropics, that there evaporation exceeds the quantity of rain which falls. Besides, on considering the immense space which the ocean covers, the more constant and equable evaporation from its surface, and the smaller quantities of rain that fall over that medium, it may at first sight be supposed, that these two processes do not bear a proportion to each other. It was the above circumstances which first gave origin to the opinion of the decomposition of vapour in the atmosphere; but, from what has been already stated, it does not appear that this ever takes place. It therefore affords a subject of interesting inquiry, to ascertain what becomes of the quantity of vapour that is raised within the torrid zone, and over the ocean in general; this being greater than the rain that falls in those situations. It is, in the first place, reasonable to suppose, that the rains which fall in the temperate and frigid regions of the earth, are supplied in considerable proportion from those sources of evaporation, which is carried by the different currents of air from the equator towards the poles. It is likewise rendered probable, by experiments, that a considerable portion of the vapour in the atmosphere over every country is directly imbibed by the plants growing on the soil. This operation goes on most briskly during night. Two fig-leaves of ordinary size were found to absorb two drachms of water in the space of five hours. As all plants have therefore a power of imbibing water, though perhaps not in so great proportion as these experiments point out, it will be sufficient to account for the disappearance of a considerable portion of vapour. Dr Hales always found, that when a slight rain, or some dew, fell in the evenings, that a sunflower growing in a pot was considerably increased in weight. But M. Ek ascertained, in various experiments, that plants were uniformly heavier in the morning, whether dew was precipitated or not. From these facts, there is every reason to believe, that the leaves of plants have the power of attracting vapour from the atmosphere, and that this process goes on most briskly during night, when the moisture of the atmosphere is more abundant in the lower strata.

The general evaporation of water, and its subsequent condensation, answers the most important purposes in regulating the temperature of climates. By the cold produced in tropical countries in the formation of vapour, their heat is so tempered, as to render them habitable, which they otherwise could not have been; and the heat thus absorbed by the vapour being again communicated to the atmosphere over the temperate and frigid zones, as it becomes condensed, and descends in rain over those climates, it in this way serves to render the temperature of the latitudes nearer the poles more mild, and thereby softens the rigour of the cold season all over the hemisphere which happens to be opposite to the sun's tropic. The manner by which this is effected will appear more manifest, as we proceed in the investigation of the matter of the following section; and will afford us a subject of the most sublime reflection on the beneficent providence of Supreme Wisdom.

SECT. II.

OF WINDS.

THE causes which effect variations in the motion of the atmosphere, are so many and so complicated, that, for a long period, no reasonable theory of the nature of winds was ascertained. Indeed, until the celebrated Dr Halley published his observations respecting this meteor, the subject appears to have been given up as totally inscrutable. But the labours of that ingenious man, and the industry of succeeding travellers, have afforded us a more correct description of those winds whose tract is permanent and uniform, which has consequently led us to a more intimate knowledge of their causes, as well as other circumstances connected with the natural history of winds in general. Since the commencement of last century, many of the properties of the atmosphere have been discovered, on which the formation of winds depend. The theory of heat alone has constituted an important æra in the study of every branch of natural philosophy: but in no instance has the knowledge of its effects been of greater advantage, than as elucidating the subject of aërology. Besides the direct influence of caloric upon the air, the knowledge of its general properties enables us to ascertain the effect of many other causes, in creating agitations in the atmosphere, which would have otherwise remained unknown: therefore, while the subject continues to be investigated on principles of experimental philosophy, we have every reason to expect, that at a period not very remote, we shall be put in possession of every explanation respecting the formation of this phenomenon.

Wind may be defined to be a portion of the atmosphere, flowing to a certain point, with a degree of velocity greater than its usual rate of motion. The causes of this increased celerity seem, in general, to be such as produce a partial condensation or rarefaction of the air. It has been formerly pointed out, that there is every reason to suppose, that the surface of the atmosphere itself is in a state of equilibrium, or approaching to it; but being of unequal density over the different latitudes, the height of its column must therefore decline from the equator to the poles. This variation of its density gives rise to a general current of air, which flows reciprocally at all times from one of the poles towards the line; the denser air over the former latitudes passing forward to occupy the place of that which is more rarefied within the torrid zone. Though this wind is permanent in a certain degree, it must evidently alternate in point of force in the north and south hemispheres, according to the season of the year. Thus, from the vernal equinox to the summer solstice, on the north side of the equator, the current from the pole is found to be stronger and less easily deflected than at any other period. In the southern hemisphere, on the contrary, the wind from the south pole is strongest during the period that intervenes between the autumnal equinox and the winter solstice. These winds do not always blow with an equal force, nor exactly in the same direction. The current from the north pole towards the equator generally sets in about the vernal equinox, and continues to be the most prevalent wind in this country till some time after the summer solstice. It appears on the eastern coast of Britain as a north, north-east, and east wind, occasionally varying its direction a point or two.

The course of the sun in the zodiac, occasions that planet to be vertical over the equator, at two different periods of the year: once in ascending to the most northerly position, and again in approaching the southern tropic; the atmosphere within these limits being more heated than in any other latitude; the influence of the sun's rays being more constant, and of nearly the same degree of intensity through every season; the current of air within the tropics is therefore found to flow always nearly in the same direction, and with the same velocity. It is on that account denominated a general or permanent wind, and is known to Europeans by the name of the north and south trade-wind, according as it occupies the north or south tropic. When local circumstances interrupt the uniform influence of the sun's rays within the tropics, as high mountainous countries, or frequent intersections in the ocean with large islands, or continents stretching into it, variations of the general trade-winds are thereby produced; and these variations constitute what are called periodical winds, as they have an alternate course, according to the sun's position in the ecliptic. These winds chiefly occur in the Indian Ocean, and in the gulfs and straights communicating with that sea, the regular course of the trade-wind being there interrupted. There is likewise other periodical winds which have their course without the tropics: these are the ornithean and etesian winds of Greece, which probably have their origin from the operation of a similar cause as the above. There are also winds frequent in every country, which always arise from causes depending on local circumstances: these are generally owing to the effects of caloric, on the soil, situation, and other circumstances which occasion a variation of climate. Whirlwinds are in every respect peculiar: their phenomena, and probably their causes also, are different from those of other winds. Deflected winds are such as, by local interruptions, are turned into a different course from that in which they had been previously blowing. Winds are rendered irregular, by whatever alters the condition of the atmosphere in a less extent, than the causes producing any of the former currents of air; as the occurrence of a water-spout, a thunder storm, a fall of rain or snow, or the quantity of vapour in the atmosphere being partially superabundant. All winds are said to rise with the flow, and fall somewhat with the ebb of the sea; and even the most violent and long continued gales have been observed to vary from night to day. The trade-winds are never so strong during night; and the north and east winds which prevail over Britain in the spring season, are likewise observed to undergo a similar abatement of their force. The changes of the direction of winds take place most frequently during night. Lord Bacon observed, that storms of wind most usually rise some hours before an eclipse: and Acosta found, that in Peru winds blow most violently about full moon. The atmosphere must have a motion in some degree corresponding to the diurnal motion of the earth, which will be therefore in proportion to the velocity of the latitude in any given place; but as the great fluidity of the air causes a continual change of situation in different portions of it, and as the earth does not move at the same rate of velocity at the poles as at the equator, but decreases in proportion to the distance from the latter, it is therefore probable, that the motion of the atmosphere rarely or never corresponds exactly to that of the latitude over which it is diffused. On account of the greater velocity of the earth's motion at the equator, it is found, that a current of air flowing from that quarter to either of the poles, has a much quicker motion than that of the latitudes over which it passes; it therefore necessarily takes a course from the west. Again, when the current sets in towards the equator, as the motion of the air is in this case slower than that of the latitudes nearer the line, it will fall behind the globe in its course, and will therefore appear to meet the earth in its diurnal rotation, and in this manner come with a direction from the east.

Winds do not always move with an equal degree of velocity: those moving towards the equator, are always much slower than those which take an opposite direction: a north or north-east wind is never violent in the north of Europe; and all the gales that take place in Britain, and on the western coast of the continent, take their course from the south-west: and it will in this way become evident, that the greatest storms occurring over the northern hemisphere, can only take place when the current blows from the tropics, either direct or deflected. It has been observed by Richard and others, that deflected winds are much stronger than the regular currents from which they originate. There are winds which have their names from the great velocity and peculiarity of their motion; as hurricanes, whirlwinds, tornadoes, &c. but which evidently belong to the same class, being produced by similar causes, and which only differ in their degree of force.

The degree of the velocity of winds, has been estimated by several philosophers, but the investigation is so very difficult, that the exact calculation is not probably yet ascertained. Dr Derham did not suppose, that the most impetuous wind flows faster than sixty feet in a second; and M. Mariotte could not make his calculations amount to more than half this rate. Mr Smeaton gives a result different from both, in a calculation communicated to him by Mr Rous, of which the following is a table.

TABLE *of the Velocity of Wind.*

Velocity of wind.		Perpendicular force on 1 sqr. ft. of averdup. lbs.	Terms of the wind.
Miles in 1 hour.	Feet in 1 second.		
1	1.47	.005	Almost calm.
2	2.93	.020	Just perceptible.
3	4.40	.044	
4	5.87	.079	Gentle breeze.
5	7.33	.123	
10	14.67	.492	Pleasant fresh gale.
15	22.000	1.107	
20	29.34	1.968	Very brisk.
25	36.67	3.075	
30	44.01	4.429	High winds.
35	51.34	6.027	
40	58.68	7.873	Very high.
45	66.01	9.963	
50	75.35	12.300	Storm or tempest.
60	88.02	17.715	A great storm.
80	117.36	31.490	A hurricane that tears up trees, and carries houses before it.
100	147.70	49.200	

But it is probable, that some winds exceed any calculation that has yet been attempted of their velocity. Mr Dalton has drawn up the following table, which gives a general view of the rotary motion of the atmosphere for every 10 degrees. The calculation is made in the following manner: he supposes the hourly rotary motion at the equator to be only 1000;

and the effect of this motion in accelerating the velocity of the wind, being as the fluxion of the cosine of the latitude, its fluxion being supposed constant.

Degrees of Latitude.	Hourly rotary velocity of the parallels in English miles.	Differences of their velocity.
0	1000	.
10	984.8	15.2
20	939.7	45.1
30	866	73.7
40	766	100
50	642.8	123.2
60	500	142.8
70	342	158
80	173.6	168.4
90		173.6

" From this table it appears, the effect of the earth's rotation to accumulate the relative velocity of winds, is about three times as great at the poles as at the equator. By *relative velocity,* I mean all along the velocity of the wind relative to the earth's surface, over which it blows: hence the relative velocity, and direction of the mass of air from the equator, is at first altered very slowly, and afterwards more rapidly, by the earth's rotation; and *vice versa* with respect to that from the poles." It has been ascertained by general observation, that winds flowing with greater velocity than common, are much more limited in their tract, than those which have a more constant, but slower motion. Storms of wind have been frequently known to pervade a whole continent; but in those instances it has rarely occurred, that the width of the current has been in proportion to the extent of country over which they have passed. It has been supposed, that the altitude to which winds reach in the atmosphere must be very great; as storms are more frequent in hilly countries, and such as are otherwise of a high local situation. Winds are constantly violent on the summit of the Andes, Teneriffe, and other very high mountains; and aërial travellers have frequently met with a fresh gale in the higher parts of the air, when it was but moderate below, and sometimes the current flowing in an opposite direction. This circumstance is frequently perceived in every climate; but from what has been already remarked of the state of the atmosphere, when treating of the negative and positive electrical states of its different strata, there can be little doubt that these opposite currents are likewise established by the operation of the same cause, viz. the different courses of the vapour raised while the sun is upon the horizon, and during his absence. The altitude to which winds reach, does not perhaps depend so much on their velocity, as on the permanence of the causes producing them: it seems therefore probable, that the slow uniform currents flowing from the poles to the equator, or the winds constantly met with within the tropics, ascend much higher than those of greater force, and whose appearances are irregular, and of short duration, and whose causes are more limited in their operations. The winds experienced on the top of Pinchinka, and other similar situations, cannot be adduced in support of a contrary opinion, as these probably owe their origin to the interruption of more regular currents of air, deflected from their usual course, by the barriers presented by the mountains themselves.

Winds have a considerable effect in modifying the temperature of climates; and an intimate acquaintance with their causes and effects, is highly essential in the practice of medicine and agriculture. Navigation likewise depends considerably on a knowledge of the same circumstances: it is therefore necessary to attend more particularly to the most remarkable of these, and to point out the causes of their varieties, so far as our knowledge will permit. To offer a minute history of the winds, as they occur in different situations during the various seasons of the year, does not enter into the plan of this work, nor would it improve the purpose for which these general observations are intended; a particular detail of which, more especially belongs to the topographical history of any particular country, and must be attentively studied wherever it is intended to promote agricultural knowledge.

During the winter and spring months at Petersburgh, the wind blows 93 days from the W. N. W. and S. W.; 54 days from the E. N. E. and S. E.; 20 days from the S.; and 14 from the N. During the summer and autumnal months, the wind prevails 78 days from the W. N. W. and S. W.; 52 days from the E. N. E. and S. E.; 22 from the S.; and 32 from N.: therefore, those from the west are most general, next are those from an easterly point. The most prevalent winds at Copenhagen are the S. E. and E.; the N. and W. blow most frequently at Stockholm, those cities lying between 56° and 60° N. lat. On the shores of the Baltic, a considerable difference is produced in the general winds, of places by their situation in respect to that sea. Britain, throughout its extent from 50° to 60° N. lat. has a considerable uniformity in the winds that prevail over it: the number of days the western wind blows, is about double of those from all other points, taking London and Edinburgh as the standards of observation for the whole island. In Ireland, the most prevalent wind for the year is from the W.; and, as in Britain, there also the north-easterly currents are most predominant in the spring. The south-west winds that prevail in Britain, and the rest of Europe, are to be regarded as currents of air flowing from the tropics, and having their velocity more accelerated than the latitudes over which they pass. They commonly bring rain, owing to the great quantity of vapour contained in the atmosphere over the more southern latitudes. As the velocity of winds from a north or easterly point is much slower, they appear to meet the earth in its diurnal rotation. A north wind always brings intense cold weather, and its particular direction seems owing to its very great density giving it a rate of motion nearly equal to the latitudes over which it passes: these winds are therefore most prevalent, when the northern hemisphere begins to be most inclined toward the plane of the earth's orbit. Dr Darwin supposes the south-east winds to be north-east currents, deflected and turned back by a stream of air of greater force beginning to flow from the equator. In like manner, north-west winds seem to be currents previously flowing from the south-west, deflected from their direction by the force of the current setting in from the pole; the former taking an easterly course, in consequence of not having acquired the velocity of the latitudes over which they had passed; the latter appear from the west, by having acquired a superior rate of motion in coming from latitudes more to the south.

On the western coasts of France and the Netherlands, the west wind prevails; on the southern coasts of the former country, north winds are most predominant. In Germany, the winds vary in situations as we approach to, either the Baltic Sea or the German Ocean: thus, in the higher provinces of the empire, easterly winds prevail; whereas in the lower, and those nearer the sea-coasts, at Berlin, at Manheim, &c. they are oftenest from the west.

The winds vary greatly in the different cantons of Switzerland, which is occasioned by their situation amidst the Alps. At Berne the most prevalent winds are north and west. At Lausanne the north-west and south-west are most frequent, and nearly divide the year equally, but do not recur at regular periods. At Milan, the most general winds are easterly; at Rome, and all over the shores of the Mediterranean, they blow oftenest from the north: a wind from the same point prevails also over Egypt during the greatest part of the year. In Venice, the south-west and south-east blow nearly an equal number of days. At Constantinople, north winds are most frequent, though a south wind likewise predominates during a considerable portion of the year. On the north-west coast of Spain, a western wind is most frequent; and on the Mediterranean coast of that country, an east wind predominates during the year. At Kamtschatka, the western winds are most frequent. In Eastern Tartary, the winds are oftenest northerly, and sometimes easterly. In Cashemire, the north and south prevail through equal seasons, which is occasioned by the mountains which divide that province from east to west. In Syria, the winds are irregular, owing to the extensive sea-coast, and high mountains in the interior. At Bagdad, the most general winds are the south and north-west. At Basora, the north-west; at Aleppo, the west and north-east; at Pekin in China, the south and north prevail. A western wind blows three quarters of the year in the country about Hudson's Bay, and is also the most prevalent in Nova Scotia. In Virginia, the most frequent winds are those which blow from a western and northern direction; the south-west blows most constantly during June, July, and August; the north-west is most predominant in November, December, January, and February. Those winds prevail, in like manner, in the country about New York.

From the above account of the most prevalent winds in different places in the northern division of the globe, it will readily appear, that the west wind predominates over the western coasts of Europe. In the eastern coast of North America, likewise, we find, that north-west winds are most frequently met with; and those currents are most prevalent during the summer and autumnal months. But the observations made on meteorological subjects in the interior provinces of Asia are not sufficiently numerous to warrant us to say from what point the winds usually blow in that quarter. Over the western coast, in the southern countries of Europe, the current of air is at all times found to be more directly west during a western wind, than what is experienced more to the northward. This circumstance seems to be occasioned by the equatorial current, as it proceeds northward, flowing over a vast expanse of ocean, and meeting with no direct opposition to the velocity of its current; it therefore naturally takes a western direction, which must be increased as it approaches land, by displacing the more rarefied atmosphere which covers it. These general winds, by sweeping over the swamps, lakes, and high lands of North America, are felt to be much colder than similar currents blowing over parallel latitudes in Europe; and, in this way, they tend to lower the mean temperature of the climate in latitudes over which they spread. It is probable, that planetary influence has a powerful effect in giving a tendency to western currents in the atmosphere every where. M. Lambert has shown, that a considerable westerly current is established in the atmosphere over the equator by this power: and, in consequence of the excessive mobility of this medium, such an effect from any cause will be greater and more general than in a fluid of greater density. The same cause is likewise supposed to occasion the hurricanes so frequently experienced within the limits of the trade-winds. M. Monier has likewise shown, that the tempestuous winds that are often experienced about the equinoxes, are occasioned by the combined influence of the sun and moon. He has remarked, that when the moon passes the meridian above or below the horizon, it occasions a strong east wind, which dissipates the clouds, or a strong west wind with rain. This is most frequent about new or full moon, and when these planets are most distant from the equatorial line.

The most prevalent winds in the higher latitudes of the southern hemisphere, are from the south; and they stretch undeflected much nearer to the equator than the corresponding winds from the north pole. The south wind prevails almost constantly in Peru; and, from the vast extent of ocean over which it blows, that country is commonly covered during the winter season with thick fogs. In the Bay of Panama, from 6° to 8° of N. lat. the prevailing winds are easterly; and from the south from September to March; and again from March to September, south-south-west currents set in. From Cape Blanco to the 4° of S. lat. when the wind that blows from north-north-east has begun to be felt in Panama, it stretches gradually to the south, dissipating the fogs brought on by the winter's wind. At this season, calms and occasional gales are frequently experienced on that coast, till the wind from the south resumes its superiority. The stormy weather that is commonly experienced at all seasons about the Straits of Magellan and Cape Horn, does not, however, seem to be owing to the constancy or violence of the south wind; but, according to the opinion of Richard, it seems more probably occasioned by the descent of the denser air from the high mountains which run through South America, and which is propelled with greater force in consequence of being a deflexion of the south trade-wind: this being interrupted and broken by the irregularity of the country in the vicinity of those straights, will be thereby increased in force, and which is probably occasionally augmented, by its collision with the current setting in from the south pole. This opinion seems probable, by finding the weather considerably more calm and moderate, at the distance of one or two degrees farther to the south, where the influence of the deflected current does not reach.

The trade-winds occupy certain limits on each side of the equator, and take their direction from east to west, with a deflection from the north or south, more or less direct according to the sun's position in the ecliptic. During the equinoxial periods, the air flows more directly from the east; but as the sun ascends either in the northern or southern tropic, these winds vary from this point, and differ on each side of the line. Thus, during summer, on the north side of the equator, the general current varies, and becomes more easterly: the air in the higher latitudes of the southern hemisphere being then more dense, will therefore take a more direct course, approaching nearer to the limits of the south trade-wind, and, thereby following the diurnal course of the sun, will form a south south-east current on the south side of the line. But, as the air is more uniformly rarefied though the whole extent between the equator and the tropic of cancer, at this period, therefore the trade-wind on the north of the line becomes more easterly. This appearance is reversed, when the sun approaches the south tropic: in that season, the current sets in more directly from the north, and forms a north north-east wind on the north of the equator; but, owing to the greater rarefaction of the air at this season over the limits of the south tropic, the south-east trade-wind takes a course more directly from the east. But the more easterly current of the trade-wind on that side of the equator where the sun happens to be, is evidently occasioned, in a considerable degree, by the greater influx of air from the pole, descending in consequence of its specific gravity over the plane of the hemisphere then most inclined toward the sun; and thereby establishes an easterly current, to a certain degree, from the pole to the equator. The extent over which these winds blow, is the space contained within the tropics, and stretches from between the 30° or 28° of north latitude to the 30°, and in some places the 32° of south latitude; nevertheless, the trade-winds do not blow uniformly throughout this space, but suffer considerable variations, according to the position of and proximity to the land. The interior limits of the trade-winds are within that space which lies between the 10° and the 4° of north latitude, where no regular current of these permanent winds can be discerned: within this tract, storms of the most violent kind are occasionally experienced; calms in the ocean, water-spouts, deluges of rain, whirlwinds and thunder storms, are met with in succession. Various opinions have prevailed, at different times, in order to account for this situation of the internal limits of the north and south trade-winds. As the causes generating those winds must be equally permanent on both sides of the equator, it appears reasonable to expect, that this point should be situated where the mean annual heat and diurnal motion of the earth are both greatest: but actual observation has shewn, that this circumstance does not take place, otherwise we should find the internal boundaries of the trade-winds limited to the proximity of the equator: the rotary motion of the earth is there greatest: we should likewise suppose *à priori*, that the highest atmospherical temperature should also exist at this line. Several causes were formerly pointed out, when treating of the temperature of climates, which appear to act in diminishing the temperature of the southern hemisphere below the common heat of parallel latitudes on the north side of the equator. These causes, therefore, have the effect of occasioning the greatest annual heat to exist somewhere on the north side of the line: but although they must have a powerful influence in this respect, the circumstance seems more evidently to admit of explanation, in consequence of the peculiar figure of the earth itself. Geometricians have discovered a difference in the dimensions of the north and south hemispheres; and by calculating its division through its equatorial diameter, in a line perpendicular to the sun, the south hemisphere is found to be smallest. During the winter, on the north of the equator, the earth passes over the least division of its orbit, which it performs in a period of time nearly eight days less than it takes in going over the northern hemisphere; and as this makes the summer proportionally shorter in the southern hemisphere, there is thereby a continuance of summer weather nearly sixteen days longer in the latitudes north of the line, or, according to Cassini, the summer of the northern hemisphere contains, in round numbers, 190½ days, while the opposite hemisphere only consists of 174½ days, during the similar season. From this cause alone, the heat of the northern latitudes must be proportionally greater; and this circumstance, co-operating with the causes formerly mentioned, will assign the point of demarcation for the interior limits of the trade-winds, to exist north of the line, which is accordingly found to occupy the space above mentioned. Within this tract no regular winds can be traced, the ocean being alternately tossed with hurricanes and tempests, or in a dead calm. This various weather is not only common on the African coast, opposite Guinea, where these variations are most violent, and occur most frequently; but they are likewise met with in the Bay of Arica in America, where, within thirty or forty leagues of the coast, calms and succeeding strong gales are common. The authors of the Dictionnaire Encyclopedique have attempted to account for this appearance, by supposing, that "this space is equally exposed to the west winds that blow upon the coast of Guinea, and the trade-wind from the east; the air in this manner has no particular tendency, and is thus, as it were, in equilibrium:" But this theory does not by any means afford a satisfactory explanation of the circumstance: neither is it better elucidated by the following opinion of the Count de Buffon, though it is very likely that both causes may have a partial effect in producing occasional variations in the regular current above mentioned. The Count thinks, "that when these opposite winds, (south and north trade-winds), reach this place at the same time, as at a centre, they cause whirlings and circular motions in the air, by the opposition of their movements, as contrary currents in water produce gulfs and whirlpools. But when these winds meet with the opposition of other winds, which counteract their action at a distance, then they turn around a very wide space in which there reigns a perpetual calm: it is this which forms the calms we now speak of, and from which it is often impossible to get out." But, in opposition to this opinion, it is to be observed, that the trade-winds blow on both sides of their internal limits, in a course that never can cause a collision or interruption of their currents, and without the agency of some very powerful and permanent cause, these would naturally blend with each other; and if either of these opinions were correct, the spot where this changeable weather must have prevailed, would be found to occupy different situations, according to the sun's position in the ecliptic; we shall therefore state the opinion of Abbé Richard on this subject, which offers a more philosophical explanation of the cause of this phenomenon. It appears, that in every coast opposite to where those calms and tempests are frequent in the ocean, the soil is either rocky, or solely consists of sand in the interior: the atmosphere over them being thereby heated to a greater degree by the stronger reflection of the sun's rays, in this way a current of air is established towards this situation from the neighbouring districts. The atmosphere, which in that country flows westward, becomes likewise gradually more heated from the same cause, and therefore moves but slowly towards the ocean, its course being hardly perceptible; the atmosphere, from points more to the south-east and north, carried on by the impulse of its own weight, flows again into this space, which in its turn speedily acquires an increase of temperature: it is therefore supposed to be this simultaneous direction of contrary currents of the atmosphere toward the same point, that produce the variable state of the weather in those latitudes. These winds are however much loaded with vapour; and as they are gradually pressed in succession upward, the exhalations they contain become condensed at a height much greater than in ordinary situations. A cloud, formed in these circumstances, and seen through an atmosphere so highly rarefied, becomes visible at an immense height: this has been called by the sailors a Bull's Eye, from its peculiar appearance; and is well known to navigators as the immediate precursor of a storm. This rapidly increases after having become visible; and as it descends, a great quantity of rain is precipitated in a very short time: this destroys the equilibrium of the most general current, and causes variations of the wind from every point; the various currents assuming a course where the resistance is least. In such circumstances, ships have felt as if struck on every quarter at once by different winds; and when a fleet happens to be exposed to such hurricanes, it commonly falls out, that as it ceases, every ship appears to be sailing with a wind different from that of the others. We must next attend to variations that take place in the direction of the trade-winds themselves. The trade-winds are not perceived to blow on the African coast, nor do they appear regular till about 100 leagues from off the coast of Guinea. On approaching the American coast, they seem to be more easterly, and to spread farther to the north; while they evidently stretch a degree more to the south on the opposite side of the equator, than what is experienced on the coasts of Africa. The trade-winds become weaker in their course westward, and they are found to extend as far as the 32° on both sides of the equator, gradually ceasing to blow as we approach their utmost limits. On the coast of Chili and Peru, the south-east trade-wind is at all times prevalent. Immediately adjacent to the African shores, in the space where the trade-winds are not experienced, from about the Cape de Verd isles, for about 500 leagues opposite the coast of Guinea, no regular current of air is observed; thunder storms, with heavy torrents of rain, hurricanes, and harassing calms, succeed each other alternately; but there is a long space in this ocean, from the heights of Ilheo to the island of St Thomas, where the south and south-west winds blow constantly in a tract of a hundred leagues in length, from 1° beyond the tropic of capricorn, to under the line; and south south-east having passed the line. These winds are only felt near the shore, where likewise the harmattan frequently prevails. Similar deviations from the regular course of the trade-winds take place within the tropical latitudes on the western coast of South America; being north-west along the coast as far as the 10° N. lat. for several leagues distant from shore, and south-west on the coasts within the limits of the trade-wind south of the equator. These deviations from the permanent winds are occasioned by the bending of the coast inward on both continents. On the African shore, the coast begins to recede, from the most southerly point, as far as the heights above mentioned. This tract of the African continent being exposed to the most intense rays of the sun, has its atmosphere at all times much warmer than the air over the adjacent ocean: this establishes a current toward land, which suffers but a slight variation, according to the latitude of the place and the season of the year; but it affects the regularity of the trade-winds to a considerable distance from shore.

The trade-winds blow, therefore, from the north-east, as far as the 10° on the north side of the equator, and from the south-east from 4° N. lat. southward, subject, however, to the irregularities already mentioned. They blow most fresh about mid-day, and are calmest during night. They blow constantly from the African coast, across the Atlantic, to the Brazils; and their force is said to be weaker in sailing westward, over the Pacific Ocean. From the American coast to the adjacent shores of Asia, including the Philippine Isles, through the whole extent of the Pacific Ocean, these winds blow more uniformly than in the Atlantic, owing to the greater extent and uniformity of the medium over which they take their course. The trade-winds do not blow through the Indian Ocean. The continents of Asia and Africa, which lie within the limits of their course over this portion of the globe, give occasion to the appearance of a periodical wind, thence named monsoon.

The cause of the permanent and regular appearance of the trade-winds seems clearly ascertained, as being occasioned by the influence of the sun's rays on the atmosphere within the tropics: probably the tides in that fluid, as supposed by the ingenious Lambert, may also have a considerable effect in giving them a westerly direction, which it must otherwise have, in consequence of the general currents of air flowing from the poles towards the equator, and which fall into the stream of the trade-winds about the 32° of N. and S. latitudes. The velocity of these currents being less than the rate of motion of the latitudes over which they flow, will naturally give the appearance of an east wind on each side of the equator, within the limits above mentioned. As the air cools, and becomes more dense, when the sun has passed some degrees to the west, it will likewise unite with the currents from the poles, and in this way increase their velocity westward. But, besides the power of these causes in giving rise to the regular appearance of the trade-winds, Dr Hadley, and afterwards Mr Dalton, states an opinion on this subject, which merits the fullest consideration. These philosophers imagine, that the velocity and uniform course of the trade-winds are occasioned in a great measure by the greater celerity of the earth's motion within the tropics. But it is to be observed, that were this increased motion of the earth within those limits the principal cause of the appearance of the trade-winds, we should expect to find similar currents far beyond the latitudes within which they are confined; and indeed an eastern current would then take place, in a greater or less degree, from the poles to the equator.

The monsoon, or periodical winds, occupy the same degrees of latitude in the Indian Sea in which the regular trade-winds are found to prevail constantly over the Atlantic and Pacific Oceans; and they are evidently occasioned by the operation of similar causes. From the 10° to 30° of S. lat. the south-east trade-wind prevails constantly, from a few degrees east of Madagascar, to nearly the island of Java and New Holland, where it comes within the range

S 2

of the monsoons; but to the northward of this line, as far as the 22° of N. lat. the monsoons have their course, and vary in the direction of their current with the season of the year. From the 10° to the 3° of S. lat. and towards the north, through the Indian Ocean, as far as the Bay of Bengal, and from Sumatra to the coast of Africa, the monsoons blow one half of the year in one direction, and in an opposite course during the other season. These winds are found to be much more regular out at sea, and suffer a considerable variation by proximity to land.

The monsoons have been generally reckoned as blowing regularly for six months from the south-west, and for an equal period from the north-east: but this is not strictly accurate; for although these are the most constant points from which those winds blow during the year, yet they are never found to succeed each other immediately, or so distinctly as to give them a decided character; but after the one ceases to blow regularly, and before the other commences, frequent hurricanes, and strong land and sea breezes, are met with in their usual tract. The monsoons, similarly to what takes place in the course of the trade-winds, vary from local circumstances, latitude, &c. and are even not similar at different distances on the same side of the equator. The monsoon, which blows from the south-west through the Indian Sea, north of the line, is found to have a south-east current south of the equator; and the monsoon which prevails from the north-east over the same tract, blows north-west from about 1° south of the equator, as far as the 10°. This variation arises from the difference of velocity in the motion of the earth in the latitudes within the limits of these winds. While the current is easterly north of the equator, it becomes western having passed that line; and, in the same manner, an easterly current south of the equator becomes western on the north side of it.

The appearance of the monsoons is evidently in consequence of the power of the sun's rays in heating and rarefying the atmosphere over a surface of unequal density, in the great extent of land and ocean which that luminary passes in his course through the tropics. As the sun ascends in the tropic of capricorn, the atmosphere over the sea and land on the south side of the equator being then more heated, it occasions a north-east monsoon to set in from the Bay of Bengal and the Gulf of Arabia, to the 3° of south latitude, which becomes north-west from this degree as far as the 10°, in consequence of the denser atmosphere over the mountainous parts of India and China, as high as Thibet, Balliagat, and the Napal mountains, moving in that direction to occupy the place of the highly rarefied atmosphere within the south tropic, the sun being then perpendicular above the south extremity of Africa, and coast of New Holland: these should therefore be the prevailing currents from the 22d of September, when the sun passes to the south of the equator, till the 23d of March, when he returns to the north tropic; but this monsoon only begins to be sensibly strong towards the end of October, and it continues till March. On the coast of Sumatra, north of the equator, as also on the coast of Camboi and China, the north-east monsoon becomes more northerly, being commonly north by east. After the winter solstice, on the north side of the line, when the sun again approaches the tropic of cancer, and by the time he has reached 7° north, the south-west monsoon begins to be felt. This current is occasioned by the rarefied atmosphere over the north-east of Asia, and the midland parts of Africa, being replaced by denser air from over the Indian Ocean, and the situations that were heated while the sun was in the south tropic. As these currents come from south latitudes, where the earth's motion is less than at the equator, from the 10° south latitude to the vicinity of the equator, the direction of this monsoon is south-east; and in June, July, and August, is merely a continuation of the trade-winds, which occupy certain limits in the Indian Ocean. It is however nearly south along the coast of Malacca and China; but from the equator, over the Indian Ocean, and through the

Bay of Bengal, this monsoon takes a south-west direction, having acquired a degree of velocity corresponding to the motion of the earth at the equator; it therefore moves at a greater rate than that of the latitudes northward, over which it blows. This monsoon is distinctly formed about the end of April, and continues to blow till September. Besides the monsoons, there are other regular winds which prevail in the gulfs, and on the coasts of the. Indian O-cean, which seem to be deviations from the re-gular trade-winds or monsoons, caused by lo-cal circumstances. In the Molucca isles, a westerly wind begins to blow in January, and continues for six months till June; and in June, July, and August, there occurs frequent hurricanes from the north. In September and October, the wind becomes easterly, and north during the rest of the year. In the Peninsula of India, the monsoons undergo the most con-siderable variations, that country being com-pletely divided by a chain of very high moun-tains, running nearly from south to north. The south-west monsoon, which blows strongly on the Malabar coast, on the western side of the Balliagat mountains, is scarcely felt on the Coromandel coast, on the opposite side, except at the most southern extremity. Again, the north-east monsoon, which blows smartly on the Coromandel side of the Peninsula, is scarcely felt on the Malabar coast, a degree or two to the west. On the Malabar coast, from September till April, an easterly land breeze prevails from midnight till midday, and does not stretch farther than 10 miles out to sea; and from midday till midnight, the sea breeze blows feebly from the west. These winds are occasioned by the cold atmosphere over the mountains being in a state of great density, at this season: during the rest of the year, north, north-east and east winds predominate. On both coasts, while the land and sea breezes continue during both monsoons, the wind on shore seems to follow regularly the course of the sun, and passes round every point of the compass in twenty-four hours. The prevalence of these breezes is chiefly during January, February, and the first weeks of March. When the south-west monsoon prevails on the Coromandel coast, the rainy season then takes place in India, and generally commences about the beginning of June.

From these observations, the variety of seasons on the different coasts of the Carnatic can be accounted for. Thus, during the south-west monsoon, the atmosphere, which is loaded with vapour from over the Indian Ocean, being condensed by the cold prevailing on the mountains of the peninsula, causes the rainy season on the Malabar coast; while, on the opposite side of the mountains, ardent summer heats prevail. Again, during the north-east monsoon, the vapour that is elevated from the sea that forms the Bay of Bengal, is condensed and precipitated upon the Coromandel coast, by the agency of the same cause; while in Malabar they enjoy the warmest and finest weather during the year. Thus, all over India, the rainy season accompanies the south-west monsoon, while their dry season continues during the prevalence of the north-east wind. As far as the Japan Isles, in the sea between Sumatra and the west coast of Java, towards the east coast of New Guinea, there blows a north and south periodical wind; the north inclining to the west, and the south to the east: the northern setting in about October or November, the southern in May: these begin several weeks later than on the coast of China, and often change suddenly. During the prevalence of those winds, the weather is variable, tempests and calms alternately succeeding each other for several weeks.

From Cape Coriantes, along through the Mosambique Channel, as far up as the Red Sea and the Bay of Melinda, the winds are variable from October till the middle of January, but blow most frequently from the north, and are accompanied by very rough weather: from January to May, the wind blows north-east, and north north-east, with a dry season. South winds prevail during May, June, July, August, and September, and in these months there is a continued breeze in the Bay of Melinda; and at that season the wind is generally very strong at the entrance of the Red Sea, near Cape Guardafui, with much rain, blowing fresh several leagues through the straights.

In the Red Sea, near to its mouth, the winds blow strong from south-west, between May and October, and cause such rapidity in its current, that it is extremely difficult for ships to enter it at that season. In September the wind begins to veer to the north-east, with fine weather, and it continues in this tract till the monsoon commences in the Indian Ocean, about the end of April, then it fixes in the south, with some previous variations. The periodical winds on the Red Sea, have been observed to change during several successive years, on the 12th of April: and the wind at quarter south-east, in the Straights of Babelmandél, changed the same day to north-west. Tempests are not unfrequent on the Red Sea, and a hot burning wind often blows over it from the interior of Africa, which lasts but for a day or two. Mr Bruce gives a relation of the monsoons in the higher parts of the Red Sea, somewhat different from the above: he says, one blows from south-west from November till March, and another blows from the north-east from April till October. This, he thinks, may, in some degree, be the continuation of the etesian, or periodical winds of Greece. As the monsoons of the Red Sea owe their appearance to the same general causes which occasion the production of the periodical winds in the Indian Ocean, their seasons must therefore in some degree correspond; and the respectable authorities of Richard, Capper, and others, warrant this conclusion. The south-west monsoon frequently occurs from May to August, as far as Suez, but suffers frequent interruptions from the sea and land breeze.

At Gazaret, at the bottom of the Gulf of Arabia, the north-west wind prevails from March to September, and is cool: during the remainder of the year it blows almost directly from the south; but over the Persian Gulf in general, the wind from the north-west blows from the months of October to July, and about three months from the opposite quarter, being frequently interrupted by gales from the south-west. At Congo, on the western coast of Africa, a wind blows north-west from the middle of March till September, which is the rainy season in that country; but from September till March, the wind prevails from the east south-east. In the rout from Mosambique to Goa in India, a south wind predominates during the months of May and June, which reaches as far as the equator; but from the line to Goa, during July and August, the south south-west prevails. From Madagascar to the Cape of Good Hope, the north-west wind prevails over sea and land during April and May: it is extremely rare that the south or south-east appears there in that season. The principal winds at the Cape of Good Hope are the south-east and north-east; the latter brings heavy rains and storms in the months of April, May, June, July, and August. The westerly winds also bring fogs, clouds, and rain; but these interruptions of fine weather are but of short duration. The south-east wind predominates chiefly during the month of October, till April, and the weather is cool and dry during its continuance. We have seen, that the monsoons undergo some variation amongst the islands of the Indian Archipelago, and in the bays and channels on the shores of that sea. There is also every reason to impute to the influence of similar causes, the variation of the winds at the Cape of Good Hope: these are likewise liable to be affected by the circumstances which influence insular situations: the Cape being near to the external limit of the south-east trade-wind, is subject to irregularities in the course of its winds from all these causes.

Periodical winds are likewise frequent within the limits of the trade-winds on the coast of America, and are evidently occasioned by similar causes which generate the monsoons in India. From Cape Gracia de Dios to Cape la Velez, across the Gulf of Darien, the north-east and east blow constantly between March and November; hurricanes are frequent during the months of June, July, and August. The winds are changeable on the coast of Carthagena, in April, May, and June; a strong east north-east wind prevails, and stretches as far as Hispaniola; it is never so violent near the land. Between the months of October and March, strong northerly winds blow from the bottom of the Gulf of Mexico, which raise considerable storms, particularly in January. In the Bay and coast of Panama, which lies from 3° N. lat. to the line, from September till the month of March, the winds are easterly, and from March to September they blow from the south south-west.

There are likewise winds that are periodical in Europe, and with which the ancients were best acquainted. They blow from opposite points, at different periods of the year, and are denominated etesian and ornithian winds; it having been observed, that birds take advantage of their current to assist them in their flight when emigrating. The etesian winds commence in July, and are distinctly felt about the 21st of that month: they continue to blow forty days, and are usually preceded by slight breezes from the north for eight or ten days. They are esteemed salutary in Greece, as they cool the air, which is then much heated; and especially as, during their continuance, acute contagious maladies have been perceived to disappear. The etesian winds are strongest during day, and only begin to be sensibly felt some time after sun-rise; they cease to blow during night. Though they are said to remain only forty days, that being the period of their greatest force, yet a wind continues more or less violent from the north till the appearance of the ornithian winds early in March. The tract over which they spread is the ancient Thrace, Macedonia, and Greece; but it is very probable that they blow over a much wider space, and are perhaps to be found a great way farther north: they sweep the upper part of the Mediterranean Sea, and prevail even in Egypt. It was to the occurrence of these winds, that many of the ancients attributed the periodical swelling of the Nile. In Egypt the north north-west, or north-east, sets in occasionally so early as June, and even sometimes earlier; but during the prevalence of the etesian winds, the current becomes more directly and invariably north, and it is then in greatest force. The sea is at this time more calm than at any other season; but after this period, the winds on the coast of that country commonly change to east, north, and north-west during January and February; and in March, April, and May, the south south-east, and south-west set in, but are liable to shift occasionally to the north. The appearance of the etesian winds in Italy is by no means constant; and when they do occur, it is in a north north-east direction. In their course southward, they do not proceed beyond the tropic of cancer, where they fall in with the general north-east trade-wind, and take the common direction of its current. The etesian winds, like those which only appear at certain seasons, depend on the influence of the sun's rays over the atmosphere. At the season of the year when these winds begin to blow, it has been shown, that the northern provinces of Asia and Africa, and the whole of Europe, have acquired their maximum of temperature; but, as the atmosphere over the northern hemisphere is not exposed to an equal degree of heat, it is found, that the temperature of the air diminishes as we recede from the tropic. In high northern latitudes, the atmosphere is therefore more dense than over the latitudes farther south. This density is increased by the cold air at all times prevalent over the tops of the mountains, which at that season is increased by the melting of the snow upon their summits; it therefore descends, taking a course in that direction where the resistance is least, and naturally tends southward, the atmosphere being most rarefied in that quarter. That the melting of the snow on the tops of the high mountains, to the north of the tract where this aërial current begins to appear, has a powerful influence in occasioning the etesian winds, seems evident, from the following circumstances: they never blow during night; nor do they appear till the heating power of the sun's rays has been felt for some time after he appears in the horizon: their duration, too, is only in that period when the earth is most heated; and they gradually cease, as the sun recedes from the northern tropic, when the atmosphere over the south of Europe, and the coasts of the adjoining continent, becomes thereby cooled to a state of density, approaching nearer to an equilibrium with the air farther north. In the same seasons also, during the melting of the snow on the mountains to the north of the Black and Caspian Seas, it is found dangerous to navigate in them, on account of the strong winds and violent gales excited by this cause.

The ornithian winds commence early in March, and continue nearly as long as the former; but they are rarely so constant. Their course is from the south and west; and they have been likewise supposed to be occasioned by the melting of the snow on the mountains of Syria and northern parts of Africa. The ornithian winds blow over the Mediterranean, into Greece and Macedonia.

Besides those we have mentioned, there are other regular periodical winds common to every country, but different from the former, as they suffer an alteration or change in the direction of their course twice in twenty-four hours. They are more remarkable in insular situations, and are most distinct within the tropics, and in the temperate zone during summer: they flow from the sea to the land in the day-time, and from the land to the sea during night. The sea-breeze commonly begins about nine in the morning, is strongest about mid-day, and gradually ceases towards five or six in the evening. The land-breeze commences in the evening, an hour or two after the other ceases: it is most vigorous in the early part of the morning, and decreases gradually after sun-rise. The land-breeze is always strongest in climates where there are many mountains; and from these it often blows so fresh, that there is no access to them by shipping during night, and they can only be approached in the day-time while the sea-breeze prevails. This is the case with many West India islands, and others in the Pacific Ocean.

In the vicinity of Masulipatam, on the coast of Coromandel, the land-wind begins to blow on the first days of June, and continues fourteen days, and is very strong. The sea-breeze, all that time, does not occur. At Paulo Catté, on the coast of Camboi, the land and sea breeze prevail for two days alternately, from the 28th July to the 6th August: the monsoons then cease on these coasts. On the coast of New Spain, between Cape Blanc and Accapulco, the land-wind blows into the Pacific Ocean at midnight: and in the same way, the sea-breeze prevails during day near as far as the Havannah. In Congo, along the west coast of Africa, as far as

Cape Lopez Gonsalva, the land-wind begins at midnight, and blows till mid-day. These, and many other varieties of these breezes, are, however, merely owing to accidental circumstances in respect to situation, their causes being general, and uniformly the same every where.

These breezes are evidently occasioned by the different effect of the sun upon the atmosphere over the land and ocean. In the day-time, we have seen, that in general the air over land is much warmer than that which is over the ocean; therefore, the denser atmosphere over the latter medium tends towards the shore, and this establishes the sea-breeze, by occupying the place of the more rarefied air inland. Again, during night, the air over the ocean being then warmest and most rarefied, the denser current of air blows from the shore, and in this manner gives rise to the land-breeze.

The seasons when the sea and land breezes usually appear, the time of their commencement, and of their greatest force and decrease, fully prove, that they owe their appearance to the power of the sun's rays, in the same manner as other periodical winds are produced every where; their influence being in this instance not so great, their effects are more general, and less powerful than in the former. This affords a satisfactory explanation why these winds are found to be most remarkable within the tropics, where the atmosphere is generally warmer, but where the difference of its temperature between night and day is greatest.

We have in this manner given a description of the most common periodical winds. There are other varieties of this meteor which come next to be considered, which in some respects resemble the former; but, as they occur most frequently over a space more limited in its extent, they are generally denominated local winds. In every country, there are certain situations where local winds usually appear; and they are commonly experienced in the vicinity of high mountains, and are obviously occasioned by the operation of local causes. In the spring season, the dense atmosphere from the summit of the Alps commonly descends upon the champaign countries on both sides of these mountains; and the current is even frequently so violent, as to stretch across the Mediterranean. There is also a district of the Alps, observed by the most ancient inhabitants of Italy, where there is a particular breeze, blowing constantly in one direction in every season of the year: it seems limited to the immediate vicinity of the place where it takes its rise, and blows north north-west: the tract through which it passes, and where it seems to receive some modification, is a channel formed in the mountains, of a few miles in length, and of about a thousan toises in breadth: it blows upon Provence, and is called maestro by the Italians: it was known to the Romans by the name of circius; and Augustus caused build a temple in honour of it, in the place where it has its origin. It is not improbable, that the origin of many of the local winds occurring in mountainous countries may be owing to a similar cause; the rarefied air in the valleys being displaced by the descent of the denser atmosphere from the summits of the mountains.

There is a district in Dauphiné where local winds are so prevalent, that Abbé Richard says it may be called the cavern of Æolus. One of those local currents has its origin in the woods in the neighbourhood of Noyons, and spreads to about the length of five leagues into the country, and of about a league in breadth: it is extremely cold and piercing; but its appearance is not permanent, nor has it periodical returns. In the vicinity of Vienne, there is a hill with a small pool of water on its summit, from which tempests are supposed to originate occasionally. A similar circumstance is said to give occasion to the same phenomena on a mountain of the Pyrenées. There is also a tempestuous local wind frequent in the Grecian Archipelago, which Aristotle denominates prester, it being always accompanied with thunder and lightning. At Banda in Persia, the wind changes four times in the twenty-four hours. From midnight till day-break, it blows from the north, and is very cold: from morning till eleven in the forenoon, it becomes easterly, and rather warmer: it then dies away till about sun-set, and afterwards gets to the west, with great heat till midnight. There is a wind which blows from the desert over the south and west of Egypt, and generally continues three days: it commences commonly a few days before the Nile begins to swell, is attended with a suffocating heat, and spreads all over the Mediterranean Sea: it is felt on the coasts of Syria, as far as Constantinople: it is also experienced in Italy and in Spain, where its continuance seems longer. It is not improbable, that the wind named harmattan, which is frequently met with on the coast of Guinea, owes its origin to the same cause, as it answers in every respect to the description of this wind. In Egypt it is generally named kamsin, sciroeco in Italy, and solano in Spain: from the former country it frequently penetrates into Arabia, Persia, Diarbeker, and Bombay. The kamsin often comes in squalls or gusts, which suddenly strike one dead, if incautiously breathed. It has been observed in Egypt, that the more direct it keeps in the course of the river, its pernicious properties are in proportion diminished. It seems therefore very probable, that it is to be attributed to the long course it takes over the Mediterranean, that this wind is found to be less deleterious at Naples than at Palermo, as observed by M. Brydone, and there also, it is never so noxious as in Egypt. The bad effects of the kamsin are not so manifest on beginning to set in, as after it has continued some time. It usually commences by causing a mistiness in the air, which makes the sun appear of a blood red colour: respiration then becomes difficult and somewhat painful: an excessive langour and depression of spirits are always experienced during its continuance, though it be carefully avoided in breathing. Yet these effects are only relieved by admitting the sea-breeze, or, what adds greatly to this effect, is to inspire the vapour of water thrown plentifully over the floors of the apartments, and by hanging over the open windows blankets thoroughly drenched with it. This wind always deposites an impalpable white powder, which covers the leaves of trees, and every thing exposed to it upon the surface. It often raises the thermometer more than 20° in the space of a few hours. Its immediate effect on the barometer is not so great; but after it has continued some time, that instrument seems rather to descend. The longer continuance of the kamsin in Italy than in Egypt, is probably in consequence of a similar wind, which blows for some time from off the opposite coast of Africa, but which does not traverse the former country. The kamsin blows over the Mediterranean in a south-east direction, and was felt very distressingly at sea by Mr Brydone, during his voyage from Naples to visit Sicily.

Mr Brydone supposes, that the scirocco has its origin from the highly rarefied air over the burning sands of Africa. This opinion is supported by the observations of M. Volney: he says, that wherever this wind appears, it always blows from a quarter where there is immense deserts of sand, and that the highly rarefied atmosphere of those places being driven forward by the more dense air in their vicinity, gives origin to their properties and uniformity of appearance. During winter in the northern hemisphere, these sands being less heated, the winds which blow over them have no pernicious effect; and it is only when the sun ascends in the northern tropic, that the kamsin, with all its horrors, is produced; probably its deleterious effects may be owing, in a great measure, to the exhalations raised from the earth, in consequence of the great heat of the sun on a soil of a peculiar nature.

There is another local wind, which is met with in the interior of Africa, and by many it is supposed to be different from the last: it is known by the name of samiel or simoom: it is still more deleterious and sudden in its effects than the kamsin; and its course is much more rapid. We shall copy the description Mr Bruce has given of the instance of it which he met with in crossing the deserts: "At eleven o'clock, while we were contemplating the rugged tops of Chigre, where we expected to solace ourselves with plenty of good water, Idris cried out with a loud voice, " Fall upon your faces, for here is the simoom." I saw from the south-east a haze come, in the colour like the purple part of the rainbow, but not so compressed or thick: it did not occupy twenty yards in breadth, and was about twelve feet high from the ground: it was a kind of a blush upon the air, and it moved very rapidly, for I scarce could turn to fall upon the ground, with my head to the northward, when I felt the heat of its current plainly upon my face: we all lay flat upon the ground till Idris told us it was blown over. The meteor or purple haze which I saw, was indeed passed; but a light air which still blew was of heat sufficient to threaten suffocation. For my part, I found distinctly in my breast that I had imbibed a part of it, nor was I free of an asthmatic sensation, till I had been some months in Italy."

It is extremely difficult to assign a probable cause for the origin of this species of wind. From the accounts given by different travellers respecting the samiel, it does not seem to recur at set periods, and it is also irregular as to the time of its duration. Nor are we furnished with any circumstance, that can enable their occurrence to be predicted. The simoom has been referred to volcanic origin; it having been experienced, that during severe earthquakes and volcanic eruptions, a noxious suffocating gas is at such times generally emitted, and which is even perceived in a slighter degree on the explosion of a powerful electrical apparatus. Though this opinion seems very probable, yet its absolute certainty, or that of any other cause, has not been ascertained: this arises principally from our ignorance of the interior of that country, where these winds generally appear.

The next kind of local wind is whirlwind, or hurricane: these seem to depend on the same cause, and perhaps differ only in the former being more limited in its operation. The latter is experienced very frequently in the West Indies, on the western coast of Africa, and in the Indian Ocean; but although this meteor may be observed most frequently in those latitudes, still there is probably no country exempted from their occasional appearance. In 1768, a meteor of this description occurred in the plain between Troyes and Bar sur Sienne: "The morning had been calm and serene, though the sun was somewhat obscured by a sort of thickness in the air; the heat of the preceding day having been very great. Towards ten o'clock of the morning, clouds began to collect; the wind was variable, from east, west, and south, and increased to a violent degree, whirling round so quickly, that it seemed as if it would overturn every thing in its way; its greatest force was exerted at the circumference of a circle, the diameter of which was not less than four leagues. After it had continued about an hour, the clouds began to dissipate, and, forming a circle in the horizon, whose centre was illuminated by the sun, and its circumference defined by the dark clouds, and by the whirlings of the dust which followed the course of the wind; it remained in greatest force for an hour and a half, and then gradually began to abate; though the dust continued to move quickly round for a longer time. All this took place without a single drop of rain having fallen."

The above description conveys but a faint idea of the dreadful effects of the hurricanes, which are so often met with in tropical countries. On the 15th October 1768, one of these dreadful tempests raged at Havannah, in the island of Cuba: it continued from two till four in the morning: the most substantial buildings could not withstand its fury: 4048 private houses, and 96 principal buildings, were laid in ruins by it: many large trees were torn up by their roots: two-thirds of the fruits in the sugarhouses and plantations were destroyed. At Batavan, where the storm raged with greatest violence, the ocean exceeded its usual bounds by at least a league: 69 ships were lost or wrecked upon the coast: the storm began on the south side of the island, and went off by the north.

It has been commonly supposed, that hurricanes recur at certain periods; but this opinion has not been confirmed by recent observation. Colonel Capper denies, that those which appear in the Indian seas return at stated times: if it really were so, the difficulty of investigating their causes would be considerably lessened, but which are by no means fully ascertained. Abbé Richard, however, affirms, that such storms harassed Burgundy for many successive years, and made their appearance on the 28th, 29th, and 30th of June: they have been therefore imagined to return once a year, or every second and seventh year; but it seems a better founded idea, that their occurrence takes place most usually about the time of an eclipse. M. Volney thinks, that the cause of hurricanes is owing to different strata of air being in different degrees of density, their equilibrium being destroyed, in consequence of the condensation of the vapour in the higher stratum, thereby enabling it to overcome the resistance occasioned by the elasticity of the lower: in this state it naturally descends, and, as it falls in with the current of the atmosphere at the surface, all the appearances of this sort of meteor are thereby produced. It is on similar principles that Dr Franklin explains the appearance of hurricanes, as they occur in America. It is to be observed that whirlwinds occur with greatest violence, in countries where evaporation is greatest and most uniform throughout the different seasons. Abbé Richard imagines, that this circumstance gave origin to a very remarkable one that occurred in Burgundy, in July 1755. "An extremely dark cloud, hanging low in the atmosphere, and driven forward by a north wind, was observed to cover the surface of the territory over which the small town of Mirabeau is situated: it occasioned very singular appearances for about a league in length, and for the half of that space in breadth. Different whirlings appeared at once in this dark mass of condensed vapours; there fell some hail, and thunder was heard: the quickset hedge-rows, and most of the trees in the vineyards, were rooted up; the little river of Mirabeau was carried more than sixty paces from its bed, which remained dry: two men were enveloped in this whirlwind, and carried to a distance, without experiencing any injury: a young shepherd was lifted high into the air, and thrown upon the banks of the river, yet his fall was not violent, the whirlwind having placed him on the verge where it ceased to act. In the woods, within its circle, its effects were traced, by finding the trees either twisted or torn up by the roots; some sheep that were in the fields were enveloped and carried to a distance; several of them were killed. It unroofed the farm-houses; and after raging in this manner for half an hour, the wind shifted to the south, when the tempest immediately ceased." From the foregoing description, and considering its similarity in many respects to that of the descending water-spout, it appears extremely probable, that in many instances these depend on similar causes; and that electricity performs a most important part, in occasioning every variety of the meteor now under review, though the exact degree, or manner of its agency, cannot be readily pointed out.

There is likewise a singular variety of the whirlwind, frequent in the deserts of Africa, where vast quantities of sand are elevated by it, and driven forward like moving pillars; they are said to be diaphanous, and every one agrees that their temperature is very high. M. Adanson gives the following account of such an appearance, which he met with in crossing the river Gambia: "This column of sand seemed to measure from 10 to 12 feet in circumference, and about 250 in height: it was supported on the water by its base, and bore towards us by an east wind: as soon as the negroes had perceived it, they strenuously plied the oar to escape it: they knew better than I did, the danger to which we would have been exposed, had this whirlwind (tourbillon) passed over us; for they understood, that its most common effect is to suffocate by its heat, those it immediately envelopes: it sometimes sets fire to their hamlets of straw: they had the experience of many instances of people to whom such an accident had happened, and thereby lost their lives: they were very glad to allow it to pass at 18 or 20 toises in the rear of the sloop, and congratulated themselves to have escaped so opportunely this torrent of fire, which the sun made appear as a thick smoke. Its heat at 100 feet distance, was so very powerful, that it raised a fume from my clothes, which were all wet, though it had not time to dry them. The atmosphere was about 25° of Reaumur, and I think the pillar must have been at least 50°, to have evaporated the humidity it attracted to it. It left a strong smell, more like that given out by saltpetre than sulphur, and which remained a long time: its first impression caused a pricking in the nose, and in some it caused sneezing; in me it produced hoarseness and difficult respiration."

Mr Bruce describes the appearance of a similar meteor that occurred to him in his journey across the deserts: "At one o'clock we alighted among some accasia trees at Waadi el Halboub, having gone twenty-one miles. We were here at once surprised and terrified, by a sight surely one of the most magnificent in the world. In that vast expanse of desert from west to north-west of us, we saw a number of prodigious pillars of sand, at different distances, at times moving with great celerity, at others stalking on with majestic slowness. At intervals we thought they were coming in a very few minutes to overwhelm us; and small quantities of sand did actually more than once reach us: again they would retreat so as to be almost out of sight, their tops reaching to the very clouds; then the tops often separated from the bodies, and these once disjoined, dispersed in air, and did not appear more: sometimes they were broken in the middle, as if they were struck with large cannon-shot. At noon they began to advance with considerable swiftness upon us, the wind being very strong at north. Eleven arranged along the side of us, about the distance of three miles: the greatest diameter of the largest appeared to me at that distance as if it would measure ten feet. They retired from us with a wind at south-east, leaving an impression upon my mind to which I can give no name, though surely one ingredient in it was fear, with a considerable deal of wonder and astonishment. It was in vain to think of flying; the swiftest horse, or fleetest sailing ship, could be of no use to carry us out of this danger; and the full conviction of this, rivetted me as if to the spot where I stood." Again he remarks, "The same appearance of moving pillars of sand presented themselves to us this day; in form and position like those we had seen at Waadi el Halboub, only they seemed to be more in number and less in size. They came several times in a direction close upon us, that is, I believe, within less than two miles. They began immediately after sun-rise like a thick cloud, and almost darkened the sun: his rays shining through them for more than an hour, gave them an appearance of pillars of fire. Our people now became desperate; the Greeks shrieked out, and said it was the day of judgment; Imael pronounced it to be hell; and the Turcomans that the world was on fire."

It seems probable that it is from a similar source, that showers of sand originate, these having been experienced in countries at a considerable distance from the deserts, and even at the length of many leagues out at sea. When we consider the prodigious force of whirlwinds in general, the diversity and bulk of the materials elevated by them, no other circumstance can be so readily referred to as the cause of this appearance. Showers of ashes have likewise been experienced in similar circumstances. In the 2d volume of the Royal Transactions, Mr Robinson gives the relation of such an occurrence having taken place on board of a ship at anchor in the Archipelago, December 6. 1631, and that a shower of similar matters fell the same day on the decks of some ships coming from St Jean d'Acre, and at 100 leagues distant from the anchorage of the former. In both instances it continued to fall from ten at night till two in the morning. It is not improbable, that many unusual matters which occasionally descend from the atmosphere, owe their origin to such causes.

In every climate, winds occasionally blow, where, on account of their irregularity and great extent, their causes have been found hitherto, in a great measure inscrutable. However, winds appearing locally, and at no certain period, seem to be connected more particularly with the proportion and state of vapour contained in the atmosphere. In long continued drought, the atmosphere being more rare, is liable to be displaced by the circumjacent columns which suffer an increase of velocity of their motion, in proportion to the diminution of resistance they meet with in their course. It is therefore experienced, that temporary gales usually succeed a long tract of dry calm weather. The condensation of vapour in the atmosphere also occasions an irregular rapidity in the velocity of the air, as it forces itself into the space that has been occupied by the vapour in its elastic state. In this way, it is found, that irregular winds occur with most violence in countries which are subject to sudden and immense discharges of rain, as within the tropics; and they are most violent in those districts of a country which are most rainy: thus, the wind is generally observed to be more violent and irregular over the west coast of Britain. Dense clouds are commonly followed by a breeze of wind, especially during summer: this seems to be occasioned by the greater degree of cold in the air immediately surrounding it, in consequence of the evaporation by the sun's rays from its surface.

We have thus endeavoured to give a general account of the varieties of winds, so far as they are known, and can be of service in elucidating their causes, which we have also attempted to explain. It has been already remarked, that a continual circulation of the atmosphere is at all times going on over the different regions of the earth; and it appears, that this process is chiefly effected by the operation of the general winds from the polar regions tending towards the tropics, and by the trade-winds, in their direction westward, being deflected by striking against the high grounds of the continent of America, and the north-east of Asia, which in this manner acquire an inclination to the hemisphere opposite the sun's tropic. This tendency is increased by the gravity of the deflected current itself; and it is owing to this cause, that there is found to be an accumulation or increase of the atmosphere over the northern hemisphere during winter; it is to this circumstance likewise, that the southerly current of air is so prevalent about the winter solstice. These currents, together with the periodical stream of the monsoons, appear to supply the loss of air without the tropics, occasioned by the currents which set in from the poles towards the equator. On considering the particular direction of the trade-winds, and that the operations of their causes are almost entirely confined to the surface of the earth, it is thereby rendered probable, that the mass of air forming their currents must be comprehended in the lower strata of the atmosphere, and that the rarefied air in their course does not reach to the entire height of the atmospherical column. This opinion seems to be corroborated, by finding that the term of congelation in the atmosphere exists invariably within the limits of the trade-winds, which otherwise could not have been the case, did the heated air ascend to a great height. This low temperature of the upper strata of the atmosphere must tend greatly to repress the ascent of the current below: the circulation of air over the plane of the atmosphere will therefore be but sparing, if it really can take place in any degree. A different opinion respecting the elevation of the mass of air which forms the trade-winds, is maintained by the celebrated Franklin; and he endeavours to illustrate his opinion, by what must take place in the air of a room heated by a stove placed in the middle: but this illustration is by no means applicable in the present question: the room and the stove are both motionless; therefore the air the former contains will necessarily arrange itself according to its specific gravity: on the contrary, the heated current forming the trade-winds moves horizontally, in consequence of the earth's motion, which must be likewise increased by the superincumbent and lateral colder strata of air pressing towards this stream. Were the trade-winds to involve in their course a mass of air of such extent as Dr Franklin supposes, we should expect to find their currents taking place without interruption on the coasts of the different countries over which they pass, but especially on the western shores of America: on this coast, however, the winds pursue a very different course: there the sea and land breezes are found to extend several leagues from the shore; and it is necessary to get an offing of at least forty leagues, before meeting with the general winds. Thus, it is indisputable, that the mountainous chain of that country forms a line between two different systems of winds.—See Volney's America, p. 182.

It will appear, from what has been premised, that were the surface of the globe uniform, and of equal density throughout, the trade-winds and general currents from the north and south hemispheres would in that case be the only winds that would blow; every other current we have had occasion to mention being merely to be considered as an irregularity in the motion of the atmosphere, occasioned by the partial operation of local causes.

By the foregoing observations, it has been shown, that the permanent aërial currents within the tropics undergo a considerable variation in the direction of their course, in consequence of the change of the earth's position in its annual motion round the sun. From this cause also, the current of the atmosphere varies in a more remarkable degree over latitudes without the tropics. This variation is likewise increased by the specific gravity of the air itself, and its tendency, from that property, to acquire an equilibrium. Southerly and westerly currents of air must therefore be predominant over the northern hemisphere, from the 30° N. lat. northward, during a great part of the year: they are accordingly found to prevail from a few weeks after midsummer till near the time of the vernal equinox. This current becomes more southerly as the season advances, and is frequently nearly due south in the month of January. During winter, over the southern hemisphere, the current likewise sets in from the equator, taking a north-west direction. As the sun ascends in the north tropic, and after he has acquired a few degrees of altitude, the denser atmosphere of the polar region descends the plane of the northern hemisphere, being propelled by its greater specific gravity. In this manner, a north or north-east wind is established as far as the northern limits of the north-east trade-wind. During its continuance, the weather is generally cold and dry, and is rarely accompanied with a fall of rain or snow. It is during the season when the equatorial current prevails, that falls of snow occur in the higher latitudes of the temperate zone; and if in this case it happens to be diverted from its course, by the transitory resistance of the atmosphere from the pole, the snow generally lies till the current from the line again sets in. But while the sun ascends in the south tropic, the prevailing winds over the austral division of the globe must arise from a current setting in from the south pole; and as it proceeds onward to the equator, it will take a south-east course, more or less direct, according to the season of the year. Dr Darwin's idea respecting the cause of south-east and north-east winds, seems readily to admit of an explanation by this theory: indeed, by keeping in mind the influence of the season of the year, and the effects of local situation in varying the direction of general winds, the prevailing winds over an extensive coast may be predicted with tolerable certainty. The polar current varies in the time of its commencement, according to the mildness or severity of the winter. When that season has been mild and warm, it generally sets in earlier; the dense atmosphere over the boreal regions being sufficient to overcome the resistance opposed by the air more rarefied, in the latitudes nearer the equator: on this taking place, cold frosty weather generally sets in: this commonly occurs in Britain in the course of the month of March, and is but of short continuance.

In this manner we are enabled to comprehend more fully the great effect of winds in the evaporation of water; and likewise why certain winds, in every country, usually bring rain or dry weather. It seems to be owing to the tendency of the equatorial current northward, by being propelled by the forcible deflection of the trade-winds, that the heaviest rains in Britain are observed to occur some time between the summer solstice and the autumnal equinox; the vapour with which the south wind is impregnated, being dissolved as it proceeds over the latitudes nearer the pole.

From what has been premised on the cause of the circulation of the atmosphere, it might be supposed, that the polar and equatorial currents should be found to predominate equally during the year; and this to a certain degree will be found to be the case: for although the west winds prevail most frequently over Britain, and perhaps all over the northern hemisphere, nevertheless there is a period when the easterly winds do occur more frequently than a current from any other point of the compass: this has been already shewn to intervene from about the vernal equinox, till towards the corresponding period in autumn. The increasing force of the sun's rays, as he ascends the zodiac, by rendering the atmosphere all over the northern hemisphere more equal in point of rarefaction, seems to operate as the cause, preventing the continuance of the polar current, with unremitting flow towards the equator, during an equal period of the year; we therefore find, that as these climates begin to acquire their highest temperature in the summer, the polar current becoming gradually less strong, frequently intermits for a week or two, and has generally ceased before the approach of the autumnal equinox.

The atmosphere over latitudes north of the equator, being more nearly equal in point of temperature and gravity, and as the inclination of the earth gradually declines about the months of July and August, the wind rarely blows strong from any quarter at that period. In this way, the following table by Mr Dalton admits of illustration; and it likewise accords with the synopsis of the weather by Dr Kirwan, in different volumes of the Irish Transactions: it is drawn up from the observations of several years, made with a view of determining the months most liable to high winds, and the proportion of each.

Jan.	Feb.	Mar.	April,	May,	June,
18.	17.	8.	6.	2.	2.
July,	Aug.	Sept.	Oct.	Nov.	Dec.
3	0.	1.	7.	12.	24.

From the foregoing doctrine it will be understood, why the change of current in the air, about the vernal equinox, is rarely attended by high gales of wind in countries north of the equator; while, on the contrary, storms and hurricanes are most prevalent after the autumnal equinox, when the equatorial current has set fairly in. It is owing to this tendency to certain points in the current of the atmosphere at different seasons of the year, that we find, while the equatorial current prevails, that any commotion in the atmosphere, northward of the line, will be probably followed by similar agitations in it, over the corresponding hemisphere; the mobility of the air being so great, an impulse given to any portion of it is regularly propagated through its whole extent.

By the foregoing theory we understand why winds have so great an influence in modifying the heat of climates, and in causing variations of the weather. The warm atmosphere from the tropics, by giving off a portion of its heat, as it blows over latitudes beyond their limits, meliorates the temperature of those climates. It has been likewise mentioned, that this effect is very much increased by a condensation of the vapour it contains, in its progress towards the pole. It is probable, that from this source the necessary quantity of humidity is obtained for bringing the productions of the earth to maturity; and during winter it supplies a covering for the earth, well adapted for warding off the pernicious consequences that often ensue to plants, during the most rigorous season. On the other hand, the current of air from the pole tends to abate the otherwise too powerful influence of the sun's rays, as he ascends in the ecliptic, on matters long exposed to a low temperature. In this manner, it appears to be entirely owing to the circulation of the atmosphere, that the various regions of the earth are habitable.

This effect of the winds was well known to the ancients, and affords a sublime illustration of the benevolence of the Supreme Being. Seneca, speaking of this subject, remarks, in terms equally philosophical and sublime: "Dedit Ille ventos ad custodiendum cœli terramque temperiem, ad evocandas, supprimendasque aquas, ad alendas satorum, atque arborum fructus; quos ad maturitatem cum aliis causis adducit ipsa jactatio, attrahens cibum in summa, et ne torpeat promovens. Dedit ventos ad ulteriora noscenda, fuisset autem imperitum animal, et sine magna experientia rerum homo, si circumscriberetur natalis soli fine. Dedit ventos, ut commoda cujusque regionis fierent communia, non ut legiones equitemque gestarent, nec ut perniciosa gentibus arma transveherent." Lib. v. cap. xviii. 5. Ques. Nat.

SECT. III.

OF LUMINOUS METEORS.

The meteors that come next to be considered, are called luminous or shining, as they are produced either by the reflection of the sun's rays, or by electricity, or in consequence of the combustion of phosphorus and hydrogen gas. These last appear most commonly in combination, and they catch fire at the common temperature of the atmosphere. Meteors, depending for their cause on the effects of the luminous rays of the sun, are likewise frequently denominated iridescent meteors: to this class belong the iris or rainbow, halos of the sun and moon, parhelion and parselené, mock sun and mock moon, &c.; to the second class belong fire-balls and the aurora borealis; the third includes the *ignis fatuus*.

Of the Rainbow.

Among all rude nations, it would appear that the rainbow has been commonly esteemed as a preternatual appearance, and in their mythology a subordinate place has been usually assigned to it. The Greeks regarded the iris as the daughter of Thaumas and Electra, on account of its beautiful variety of colours; and the Romans appointed her to the particular service of Juno, with whom she appears to have been a very great favourite. Virgil says,

> Tum Juno omnipotens, longum miserata dolorem
> Difficileque obitus, irim dimisit Olympo.
>
> Ergo iris croceis per cœlum roscida pennis,
> Mille trahens varios adverso sole colores,
> Devolat, et supra caput astitit.

But the Peruvians seem to have carried their superstition in regard to this meteor to a much farther length than either the Greeks or Romans; for there was an apartment in the celebrated temple of the sun at Cusco, dedicated entirely to its worship, and servants were expressly set apart for this purpose. The Jews, too, at a remote period of their history, seem to have entertained a very fanciful idea of the purposes of the rainbow, not more consistent with its true nature, than the opinions already mentioned. The cause of the appearance of the rainbow, was by no means understood by the ancients. Aristotle describes it as being the refraction of light from a cloud; but no other circumstance is mentioned, which could tend in any degree to elucidate its nature. Albertus Magnus is supposed to have been the first who indicated the real cause of the iris; and so early as 1611, Antonio de Dominis, Bishop of Spolatia, had determined it by experiment; but the fact seems to have been little regarded during his own lifetime, although an investigation of this phenomenon has been held an interesting subject of inquiry by the learned in every æra. De Cartes bestowed much care in the investigation of this matter; but its causes were first satisfactorily explained by Sir Isaac Newton, having accurately determined the refrangibility of the primitive rays, in his analysis of light: Its nature was thereby fully developed; and on these principles it has been found, that the iris is caused by the reflection, and double refraction of the rays of light, in its entrance and exit from the drops of water in the air.

The rainbow appears only when the atmosphere is damp, and actually raining: it is most usually seen during day, though from the most remote antiquity, it has been also occasionally observed during night. It frequently appears in the vapour raised by the dashing of water, in extensive cataracts; and also in the spray of the sea. The iris commonly appears in the horizon in form of an arch, though it has been sometimes observed as a complete circle, and at other times in the figure of a small segment. The position of the sun always corresponds to the top of the bow; the spectator being placed between the iris and the sun: its height in respect of the spectator is about 42° at the top of the arch, and 40° in the under border of it: its precise figure is occasioned by the eye of the spectator, forming the summit of a cone, whose base is formed by the cloud where the rainbow appears; the central line is the axis, and around the circle the visual rays are supported; some are in the exterior of the coloured band, where they make an angle of 42 degrees; the others are formed on the intermediate circumference, where they form angles of different degrees, according to the refrangibility of the colours that are seen: thus, the particular figure of the rainbow is owing in a great measure to the position of the spectator, as well as to circumstances depending on the form of the cloud on which the iris appears. For this reason, it is evident, that different people do not perceive the same individual rainbow. The varieties of colour in the iris, is evidently occasioned by the different degrees of refrangibility of the primitive rays of light: in the double refraction these undergo in passing through the drops of water, and by being reflected to the eye of the spectator, they are presented in the same order as in the spectrum. This is satisfactorily explained by the experiments of Sir Isaac Newton; he found, that the sines of the most refrangible rays, in passing from water into air, is as 185 to that of the least refrangible 182, the sine of incidence being 138: in this way, he calculated the size of the iris: If the sun were a physical point without magnitude, the breadth of the inner bow would be two degrees; but allowing half a degree for the apparent diameter of the sun, the whole breadth must therefore be 2½ degrees: but the outermost colours of the spectrum being extremely faint, it will not appear more than two degrees. In the same way, he finds, that the breadth of the exterior bow, if it were equally vivid throughout, would be 4° 20′; but on account of the great faintness of its colours, it does not appear to exceed 3°. The sun always corresponds to the centre of the arch; if he is higher upon the horizon than 42°, the centre of the arch will be as much sunk below it; therefore no primary rainbow can be seen, but which will be proportionally more complete as that luminary acquires a just position for the perfect appearance of the meteor. The position of the sun according with the centre of the arch, and of course being within the horizon, is the reason why a circular rainbow is so rarely seen: when such a phenomenon does appear, it occurs always at sun-set, or in the spray of a cataract. The complete form of the semicircular rainbow, depends on the position of the spectator, the time of the day, state of the weather, and evenness of the ground. There is often seen a double iris, but when two are seen at the same time, the reflection from both is never equally vivid: in the one last formed, the reflection of the sun's rays is always most faint, and in an order reverse to that of the original bow. This seems owing to the same rays of light suffering a second time a double refraction and reflection, and thus a considerable proportion of these being dissipated, in passing so frequently through one medium into another. It is for this reason, also, that three rainbows are rarely visible at the same time. Aristotle has taken notice of this circumstance, and accounted for it on principles nearly consonant with the doctrine of the immortal discoverer of the compound nature of the solar rays: he says, "tres autem non adhuc fiunt, neque plures irides, quia et secunda fit languidior, ut et tertia refractio, valde debilis fiat, et impotens sit pervenire ad solem." Meteor. lib. iii. cap. iv. The above theory likewise affords an easy explanation, why a rainbow frequently appears reversed when viewed from a height, and how this phenomenon sometimes appears after sun-set. When two bows are formed, the inner always vanishes when the sun exceeds 42°; and even the upper bow vanishes when the angle of incidence of the visual rays exceeds 54°.

In the year 1757, Mr Edwards saw a rainbow in the west, just after the sun had set: the sky being overcast and covered with clouds, the rainbow appeared more elevated than they usually do. There have been rainbows frequently perceived, that did not reflect all the primitive colours; indeed, it is but rare, that the whole are visible. Don Uloa saw them entirely white on the summit of the Andes. M. Daval, in 1748, saw an iris of a green colour, approaching to yellow, one of a deeper green mixed with purple, and another entirely purple. But these and every other variety of this meteor, are occasioned by some accidental interruption of the same general cause, preventing the complete reflection of the coloured rays.

M. Bernier saw the lunar iris at two different periods, while he remained at Delhi; and Mr Tunstal gives the description of two he observed in England.

Of the Parhelion and Parselené, or Mock Sun and Moon.

The next of the iridescent meteors is the parhelion or mock sun. This appearance is occasioned by the more direct impression of the complete form of that planet on the surface of a dense cloud, which reflects the image in the order his rays have been received. Parhelia are commonly seen at sun-rise, or at sun-setting, and are almost always two in number, When the rays are divergent, there is commonly the appearance of an iris surrounding the parhelion; and it most usually occurs in this manner: Parhelia are most frequent in northern climates, and in the spring, when the evaporation begins to increase after the winter's cold. Nevertheless, they have been observed in South America, and in other tropical countries in every season: they have been likewise seen in that part of the horizon where the sun happened to be, but where there was no appearance of a cloud, the atmosphere at such times being very moist. In like manner, the parselené has been observed to accompany the moon; the air being then extremely serene, and impregnated with a sort of mist. Muschenbroeck ascertained, that parhelia could not be discerned at places a little way distant: thus, the mock suns that were visible at Haarlem on February 22. 1734, were not visible at Utrecht; nor were the mock suns that were seen on the 12th March, in the same year, at Catwyck, Leyden, and Hundkirke, visible at Utrecht. This affords a decisive proof, that the cause of this meteor must be limited to the stratum of air near to the earth's surface.

The causes producing parhelia are similar to those which give rise to the rainbow, and seem only to differ in consequence of the difference of the reflecting medium, which, according to its degree of density, produces variations in the appearances of those meteors. The rainbow seems to originate by the reflexion of the solar rays, from vapour in a state of actual condensation. In the present instance, the reflecting medium evidently exists in the state of vesicular vapour. In this way, these meteors frequently appear together, although the parhelia appear between the sun and spectator; contrary to what takes place in the formation of the rainbow. Still it has been supposed, that when the impression of the rays is direct, they give rise to an exact representation of the sun itself: when divergent beyond a certain degree, they produce the rainbow.

The parselené, or mock moon, appears most frequently in winter, and in the most perfect form when the moon is about the full: though these have been seen at every season of the moon's age, the completeness of the representation depending considerably on the density of the reflecting medium.

The cone of red light which is observed to accompany the rising and setting sun in northern countries, as in Hudson's Bay, is owing to a similar cause to that which gives occasion to other iridescent meteors. And in this instance, it seems to be the consequence of the great quantity of vesicular vapour, with which the lower stratum of the atmosphere is always loaded in that climate.

The most remarkable parhelion of which we have an account, is related by Cassini, in the 10th volume of the Memoirs of the Academy of Sciences. It was seen on January 18. 1693: except the very spot where the sun was about to rise, the eastern part of the horizon was covered with thick clouds: at thirty-eight minutes past seven, a luminous appearance was seen at this spot, which seemed in size as large as the sun, and rose perpendicularly towards the clouds: afterwards the image of the sun's disk was seen to appear through the fog, from whence issued rays perpendicular to the horizon, and in height about 10 degrees. M. Cassini, who had mistaken this meteor for the sun, was now greatly amazed to perceive the superior edge of that luminary gradually come into view, and in brilliancy equal to his appearance in calm weather. This brilliancy enabled him to distinguish it from the mock sun, which still remained fully in view, of the same size and form of the true sun, and it also illuminated the clouds by its rays. A little while after, the sun being completely hid by the clouds, M. Cassini was still more surprised to see a third sun appear immediately below, of the same size and figure, and in the same vertical line: this one had a train below, similar to what the first one had above, and which rose in the horizon. Nevertheless, the first parhelion remained, but his perpendicular rays became more feeble and shorter; then they began gradually to disappear, and at fifty-eight minutes past seven, there was no trace of them. These meteors are formed by the refraction and consequent reflection of the sun's rays; but in the parhelia, the refraction is perhaps less complete than in the formation of the iris, the reflection being more immediate, in consequence of the peculiar nature of the reflecting medium.

Of Halos.

The Halos which occasionally surround the sun and moon, fall next to be considered; these are most frequently observed to accompany the moon, and are therefore only met with during night. This meteor only appears when there is a slight fog in the atmosphere: this degree of humidity being so readily dissipated by the calorific rays of the sun, is the reason why halos so rarely accompany that planet in temperate climates. Halos seem to be occasioned by the rays of light striking against a cloud or atmosphere, which, although considerably uniform and dense, is still so rare as to allow them to be scattered at the point of incidence, and which are thus refracted and reflected from every point around, giving the appearance of a luminous circle. This appearance can be produced, by placing one's self behind any large water-work while it is playing, so that the vapour may intercept either the solar or lunar rays. A similar appearance is frequently perceived around the lights in the streets, during damp weather: sometimes a similar appearance is seen, upon rubbing the eyes; but the cause of this last is evidently in the eye itself: the contents of the glands of the eyelids, and the carunculæ lacrymalis, being thus squeezed out, and thereby spread over the cornea, causes the refraction of the rays as they reach the eye, and produce all the phenomena of an halo. Halos are not altogether colourless, though their colours are neither so various nor so vivid as those of the rainbow and parhelion: this is in consequence of the luminous rays being somewhat differently refracted, as the rays of light are scattered at the same point of refraction, and the point of reflection being the same, the circles are more or less coloured, according to the density of the medium. In the colours of an halo, the deepest shade is always in the centre of the object; towards the circumference it inclines to white, and between the luminous body and the meteor, there is always perceived a space less deeply coloured than the exterior circle. In the formation of the iris, the atmosphere must be actually raining: the parhelia and halos, arise in consequence of the refraction and reflection of the luminous rays through an atmosphere loaded with vesicular vapour, which is perhaps more dense when the former of these is produced. These meteors are also more common about Hudson's Bay, and in other parts of North America, where they are observed to be more brilliant than in Europe. They are seldom seen in warm countries, and never in the sandy deserts of Africa. The condition of the atmosphere giving origin to these appearances, does not reach high; but, on the contrary, it seems to exist in the stratum immediately over the earth's surface. Dr Darwin says, "In riding in the night over an unequal country, I observed a very beautiful halo round the moon, whenever I was covered with a few feet of mist, as I ascended from the valleys, which ceased to appear as I rose above the mist. This, I suppose, was owing to the thinness of the stratum of mist in which I was immersed: had it been thicker, the colours refracted by the small drops of which a fog consists, would not have passed through it down to my eyes." Parhelia, as well as halos, have been supposed to prognosticate storms of wind and rain: this observation has been made both by husbandmen and mariners. Dampier expressly says, that a tempest never failed to follow a circle round the sun; those which appear round the moon, rarely augur so much mischief. He also ascertained, that whenever there appears a break in the lunar halo, a storm may be expected from the corresponding quarter.

SECT. IV.

OF ELECTRICAL METEORS.

Of Fire-Balls, or Dracones Volantes.

APPEARANCES of fire gliding through the atmosphere in form of a ball, have been supposed to be occasioned by electricity: they are denominated *dracones volantes*, especially when followed by a train of a description similar to that of their body; and they are supposed to be most frequent when the actual eruption of some volcano takes place. Their appearance is perhaps more frequent that what is generally supposed; neither are they peculiar to climate or season of the year, the draco volans being met with in every country. On the 10th of August 1783, there was one visible all over Britain, and a great part of the continent: it took its course from north to south, and was supposed to have originated in Iceland, Mount Hecla having been at that time in a state of violent eruption. It occasioned a peculiar rushing noise in the atmosphere, and a smell similar to what is experienced after electrical explosions. It was calculated by Sir Charles Blagden to have moved in the atmosphere at the rate of twenty miles in a second, and to have had its course at an immense height, being, according to his calculation, about 60 or 70 miles above the earth's surface. There was a former fire-ball seen in Britain, in November 26. 1758, which was calculated to be 100 miles elevated above the earth's surface, and to have been one mile and a half in circumference. It moved towards the north at the rate of 30 miles in a second of time. This fire-ball, as well as that which appeared in 1783, threw off many sparks in its course, and had a train of several miles in length. In 1746, on the night between the 11th and 12th of June, there arose a fiery meteor in the vicinity of Ostia: it first appeared as a very dark cloud, gradually inclining to the earth, throwing out flames in its progress towards Rome, of a strong sulphureous smell: it came forward with great velocity, by a south wind, and seemed to be elevated only about three or four feet above the ground: it moved rapidly forward for about twenty miles, in a zig-zag direction, and was accompanied in its course by thunder and lightning: it overthrew trees and houses that stood in its way; out of four walls which it passed perpendicularly, two only were left standing: wherever it passed, a tremulous motion of the earth was perceived; before it reached Rome, a violent gust of wind was felt, attended with a loud hoarse noise, which the meteor seemed to occasion; it passed through the lower part of that city, where it reduced to ruins whatever opposed its course between the Tiber, the Capitol, the Horse Course, and the Pincio, shaking the houses as it went along: this meteor had been preceded by weather somewhat stormy.

There was likewise a ball of fire seen to arise out of a cistern standing in one of the turrets of the monastery belonging to the nuns of St Christian, near Bologna; it happened in autumn 1745. One of the angles of the turret had been injured in the roof for some time previously, and the rain had thereby fallen through it. The fire-ball rose with great rapidity, and striking against the top of the tower, it exploded with a tremendous noise.

In July 17. 1771, a fiery meteor was seen at Paris, Passy, Nantes, Rouen, Beaumont, Auxerne, Dijon, Dolle, Lyons, St Omers, and, according to report, it was also seen at London. At Paris it appeared of a yellow colour; was several feet in length; and accompanied by a noise like the rumbling of a waggon going smartly over a pavement. The air was calm, but the weather had been very sultry for several days before. This meteor burst in the vicinity of L'Orient, throwing out an immense quantity of sparks. The next day some rain fell, which was extremely fœtid. The ball appeared so low in the air, that it was supposed to have alighted in several other places before it actually reached the ground on the sea-coast.

It is probably owing to a meteor similar to this, that showers of fire are recorded to have occasionally happened.

We shall close this account of fire-balls, by repeating the relation of a very remarkable one of this description, which, in its effects, is distinctly shown to have been of electrical origin, and by which it will likewise be seen, that these meteors are not solely confined to land, neither do they always keep at an immense distance from the surface of the earth. The account of it is given by a gentleman who witnessed its effects: it occurred on board Admiral Chalmers' ship The Montague, and is related in the following words by Dr Priestley, in his History of Electricity:

"On the 4th November 1749, in the latitude 42° 48′, longitude 9° 3′, he was taking an observation on the quarter-deck about ten minutes before twelve, when one of the quartermasters desired he would look to the leeward, upon which he observed a large ball of blue fire rolling on the surface of the water, at about three miles distance from them. They immediately lowered their top-sails; but it came down upon them so fast, that before they could raise the main-tack, they observed the ball to rise almost perpendicular, and not above forty or fifty yards from the main-chains, when it went off with an explosion as if hundreds of cannon had been fired off at one time, and cast so great a smell of brimstone, that the ship seemed to be nothing but sulphur. After the noise was over, which he believed did not last longer than half a second, they found their main-topmast shattered into above a hundred pieces, and the main-mast rent quite down to the keel. There were some of the spikes which nailed the fish of the main-mast drawn with such force out of the mast, and they stuck so fast in the main-deck, that the carpenter was obliged to take the iron crow to get them out: there were five men knocked down, and one of them greatly burned by the explosion. They believed, that when the ball, which appeared to them to be of the bigness of a large milstone, rose, it took the middle of the main-topmast, as the head of the mast above the hounds was not splintered. They had a hard gale of wind from the north by west to north north-east for two days before the accident, with a great deal of rain and hail, and a large sea from the northward: they had no thunder or lightning neither before nor after the explosion. The ball came down from the north-east, and went off at the south-west."

Of St Helmo's Fire, or the Corpus Sanctum.

The small shining meteors which are frequently observed to alight on the rigging of ships at sea, and on elevated pointed bodies inland, have been also reckoned amongst the meteors produced by electricity. These were known to the ancients by the names of Castor and Pollux; and by later writers they are called *corpus sanctum*, comazantes, and St Helmo's fire. On the shores of the Mediterranean, from time immemorial, they have been accounted the precursors of a storm; and it is from a confirmation of this opinion of their nature, that a custom of very great antiquity is still kept up at the Chateau di Diurno in the Frioul, situated on the sea-coast. There is erected on one of the bastions of that castle, a pike planted in a vertical position: whenever there is the appearance of a storm, the sentinel who mounts guard holds the point of his halbert to the iron head of the pike: if it sparkles when the halbert is presented to it, or throws off at the point a small luminous brush, a large bell is then sounded, to warn those labouring in the fields, and the fishermen along the coast, against the approaching storm. Cæsar mentions having seen these meteors settle on the spears of his soldiers. Dampier says, he never saw them appear but they were succeeded by a high wind and heavy rain. M. Forbin gives an equally unfavourable prognosticate of the weather from their appearance. One night while he lay off the Barbary coast, it became suddenly very dark, with much thunder and lightning: the sails of his ship were furled, and more than thirty balls of St

Helmo's fire were seen on different parts of the rigging. A sailor was ordered to the topmast to drive one of them off, lest it should do mischief: as he got near it, he said that it emitted a noise like that caused by firing moist gunpowder.

Of Shooting or Falling Stars.

What are known by the name of falling stars evidently belong to this class of meteors, their effects having been ascertained to be similar to those produced by lightning. The Marionites of Mar-Elias assured M. Volney, that one of those falling stars had alighted upon two mules belonging to their convent, which killed them, making a noise like the report of a pistol-shot, and, in every respect, it had produced all the effects of a thunderbolt. It seems also probable, that the flame which is said to have been seen to play round the heads of some children is of an electrical nature. This was esteemed as a happy presage in the case of Ascanius: it was also the prelude to the good fortune of Servius Tullius, which introduced him to the regal authority at Rome.

Of the Aurora Borealis.

No description of meteor has been more attended to of late years than the aurora borealis, or northern lights. Some have supposed, that they have only appeared in modern times: but this opinion is controverted, by the relations of phenomena evidently the same, contained in the works of several of the earliest Greek and Roman authors; and an account of these is continued through the middle ages, till the present æra. The ancient poets explained the appearance of the aurora borealis, by doctrines depending on mythological opinions; this was accordingly referred to the flight of Electra, one of the Pleiades, who, in despair for the sack of Troy, forsook her station in the heavens, and, relinquishing her place in the dance formed by her sisters, went to bewail her sorrow in concealment behind the ursus major. Aristotle, Seneca, and Pliny, mention this meteor by the name of chasmata, trabes, belides, &c. This seems to have been frequently confounded by the ancients with comets: Seneca says, "Placet ergo nostris, cometas, sicut faces tubas, trabesque et alia ostenta cœli denso aëre creari; ideo circa septentrionem frequentissime apparent, quia istic plurimum est aëris pigri:" in another place he says, "Sunt chasmata cuivi aliquando cœli discedit, et flammam dehiscens velut in abdito ostentat, colores quoque horum omnium plurimi sunt, quidem ruboris accerrimi, quidem evanida, et levis flammæ, quidem candidæ lucis, quidem micantes, quidem equaliter, et sine eruptionibus aut radiis fulvi." But Aristotle had long before defined them in the following words: "Apparent autem aliquando noctu, serenitate existente, consistentes multæ imagines in cœlo, ut hiatus, foveæ, et sanguinei colores." The aurora borealis was likewise imagined to be peculiar to the northern hemisphere; but Don Ulloa saw this appearance in Peru; Dr Foster likewise observed it in the 58° S. lat. and M. Agelet within ten degrees of the line. This phenomenon is, however, more frequent in the higher latitudes of each hemisphere. There was a very bright aurora perceived in Cusco, 12′ S. lat.: it appeared on the 12th August 1744, and caused much consternation both to natives and Spaniards, who looked upon it as a prognostication of the end of time; and it was with much difficulty the governor, Marquis di Valle Umbrosa, could persuade the inhabitants that the meteor was merely the effect of natural causes, and by no means a mark of divine displeasure. Indeed, this opinion of the Peruvians seems to have very generally prevailed amongst the vulgar at all times, who have uniformly regarded the appearance of the northern lights as the portentous harbinger of war, famine, and pestilence; nay, several sagacious authors give a description of the form of the engagements, and the particular instruments of hostility, which, by the power of imagination, they saw depicted in these aërial appearances.

The aurora borealis appears to be more frequent at some times than at others, and cannot be discerned even for a long series of years. It seems to have been extremely rare in Britain during the 17th century, though there was a very remarkable one seen in 1621, of which an account is given by Gassendi, and which was apparent all over France and a great part of Germany; there were also several others seen on the continent, but none either so brilliant, or so widely extended. When the northern lights were seen in Bologna in 1723, so very scarce had they been over that part of Italy, that in the description of them in the Memoirs of the Institute, it is positively affirmed, that they had then been seen there for the first time. Cambden speaks of them as an unusual and terrifying prodigy: and they were so very rare in the days of the celebrated Halley, that he despaired at one time of ever seeing them; but it is to the observations of that ingenious man, and to the writings of De Mairan on this subject, that the most accurate account of this meteor has been transmitted. The aurora borealis generally appears only when the atmosphere is perfectly calm, though Muschenbroeck observed them in 1728 and 1733, during very stormy weather: M. Mairan also mentions a similar circumstance. It commonly begins to be illuminated early in the evening, and rarely continues longer than two or three hours past midnight. Its colour varies, yet this is oftenest of a reddish white, changing to a deeper or lighter shade, and it not unfrequently shews a diversity of colours like the rainbow. The proportion of light which the aurora borealis emits, must depend greatly on the clearness of the air; but even during its greatest illumination, the stars are never obscured. Its light is, however, said to equal that of the moon within the polar circle. On the 20th August 1708, the Bishop of Hereford observed one of these appearances in the vicinity of London; it was very splendid: and Cornelius Bruyn, returning from Archangel, in the same year, near 75° N. lat. saw, on the 15th September, a light in the atmosphere, which, though not of long continuance, its rays were so luminous as to enable him to read without a candle.

The northern lights usually appear from the time of the autumnal equinox, till the corresponding period in spring. Their figure is somewhat like the form of an arch, with a darker spot or cloud toward the north, from whence the illuminating radii issue; and, as described by Gregory of Tours, it resembles the cowl of a monk's cloak. This cloud gradually brightens up, till the whole meteor disappears. It has been generally allowed, that the corruscations of the northern lights are accompanied by a peculiar noise, resembling the rustling of silk, but louder. The Abbé Conti, who was in London in 1716, at which time the aurora borealis appeared there very distinct and vivid, makes particular mention of the noise produced by the peculiar dartings of the radii, and asserts positively, that this detonation (*detonazioni dell' aurora*) was not occasioned by any agitation in the atmosphere itself, nor by the murmurs of the spectators, though it appeared so low, that they were afraid it would have fallen upon their heads. The aurora borealis generally stretches from north-east to north-west, and is much fainter in the former quarter; in its appearance it resembles electrical light when seen in a vacuum. This meteor always commences as a mist on the northern part of the horizon, which is then clearer toward the west. This thickness in the air, commonly arranges itself in the form of the segment of a circle; the point of its circumference that is visible, soon acquires a border of a whitish light, which gradually increases, and from whence proceeds one or several luminous arches. At this period the dartings of the coloured rays commence, some from the segment of the circle, and others from the arch itself; by their motion, the space they leave always seems open: and these appearances increase in motion and vividness of colour, with a proportionate augmentation of the whole meteor. The various corruscations cause an appearance of great confusion, and it occasionally seems to vanish in part, speedily re-appearing with increased splendour. When the segment of the aurora becomes fully illuminated, and the arch in its most vivid state, the meteor may then be considered in its greatest beauty. The segment at this period, is compared to the pavilion of a tent, to which it is supposed the entire meteor bears a resemblance, as it is at this particular spot where the rays unite as into a focus. After this period, the phenomenon appears to be less vivid, its colours becoming gradually more faint, but with occasional renovation of its dartings, and of the tremulous motion of its rays; all the appearances are sometimes renewed with great brightness, but of very short continuance, and never remain so long, nor is the colour so vivid as during its increase. After midnight, it soons begins to contract itself in the meridional and eastern quarters, and it likewise becomes fainter in the portion of it which stretches to the west; it then seems to fill only the place originally occupied by the segment, which still remains longer on the horizon, of a pretty bright colour, diminishing sometimes very rapidly; at other times it vanishes in a very slow and gradual manner. In this manner the aurora borealis returns for several successive nights, with occasional interruptions: it frequently remains for several weeks, and it has been known to appear in Iceland for fifty succeeding evenings.

There was a very remarkable aurora seen, 19th October 1726: it commenced as a smoke in the north: a little while afterwards several illuminated beams were perceived to issue from it; the meteor soon appeared, like a superbly illuminated dome, and the whole horizon seemed lighted up by the vibrations of its luminous rays; these corruscations darted from the west to the south; in the former point it was most bright, and in that quarter too it seemed of a blood-red colour, which, as the night advanced, became violet. Toward the south there was discerned several white luminous clouds of a reddish tinge, stretching toward the zenith. The crown or dome changed its figure several times, and the stars were perceived very distinctly through it. About half an hour past midnight, the meteor appearing tranquil, and the sky pretty free of clouds, and of a dark blue colour, there darted from an opening in the segment, toward the east, an high coloured ray of a fiery appearance, greenish on its border; and in less than a minute, it communicated its light up to the zenith, illuminating the whole sky, as far as the south, and brought back, as it were, the luminous undulations, which lasted about five minutes, the usual appearances being thereby renewed; after this the aurora became less vivid, but remained even in a certain degree till day-break. This aurora was seen at Rome, Madrid, Cadiz, Muscow, Paris, and generally all over Europe.

There was another of these meteors, equally brilliant, and in every respect like the former, seen at Upsal, February 4. 1759. But perhaps the most remarkable meteor of this description was seen on the 18th January 1770. It was observed at Vienne, a quarter of an hour before eight o'clock, and in an instant it filled the atmosphere with a most brilliant light, and seemed as if divided into two parts, the strongest coloured was in the north-west; its colour became more dull for a moment, and was immediately replaced by a whitish light, turning gradually to a red colour, it remained so for the whole night. At first it only occupied a portion of the horizon; but in a short time it became as light as it is during full moon. There was not heard any noise in consequence of its motions, which do not seem to have been remarkable. As it went off, there fell a great quantity of snow, and the thermometer sunk six below zero. It was discerned in Burgundy between nine and ten o'clock, during a heavy fall of snow; it was also seen at Rome; but it did not produce any vibrations at that place: at Genoa and Cadiz, its undulatory motion was very great; at the last-mentioned city, it appeared about sun-set; and it illuminated the horizon over it till a little past midnight. These seem to have been the most brilliant of the northern lights which appeared during last century. There were many others observed, but none so remarkable.

The auroræ boreales are said to be pretty constant in Greenland, and over the neighbouring frozen ocean, and are most remarkable about full moon. In those latitudes, they seem to come from the north, and stretch towards the zenith in form of a pike or palisade. It darts from place to place, and leaves the space it had occupied as if filled with mist. But, though most frequent in the higher northern latitudes, it is not always visible in Iceland. Torfeus says, that when the auroræ boreales appeared there during the middle of last century, the inhabitants were dismayed and affrighted at the appearance of them, as being uncommon and awful. In Sweden, the peculiar noise caused by the dartings of the radii, is distinctly heard after every tremulous corruscation; and those who frequent the coast of Greenland during the fishing season affirm the same thing as occurring there. Gmelin pointedly remarks the peculiar noise of this meteor, as it appeared in Siberia; and we have seen, that the same thing occurred very remarkably in one that was observed at London.

Diodorus Siculus mentions the appearance of a phenomenon much resembling the aurora borealis, which was observed occasionally on the summit of Mount Ida, and was most frequently seen towards the end of autumn. It was the vulgar opinion, that the sun appeared there during night. It is extremely probable, that some circumstances occasioned by the vicinity of the Alps cause the frequent appearance of the auroræ in Lombardy; nevertheless, they are there generally more obscure, neither are their vibrations so quick as in other situations. It may also be reasonably inferred, that similar causes operate in the territories adjoining the Andes, and thereby occasion the appearance of this meteor in south latitudes near to the equator; and probably they occur most frequently in every country in the vicinity of its mountainous districts.

To ascertain the region of the atmosphere, and the height at which the aurora borealis appears, has engaged the attention of many celebrated philosophers. M. de Mairan supposed, that the aurora which appeared in 1730 was elevated 70 leagues above the surface of the earth: by the calculation of Mr Crammer, it was imagined to appear in a region 160 leagues higher than the earth's surface: and the aurora which was seen in 1726 has been estimated to exist in a region of the atmosphere at an elevation of 216 leagues. But these are all inferior to the calculation of Father Boscovich, who imagined, that the aurora 1737 was at least 825 miles above the earth; and the celebrated

Euler supposed this meteor moved in a region several thousand miles high. But it may be observed of these calculations in general, that they seem rather the result of over-refined speculation, than as formed on any true and permanent data, and may perhaps be regarded as a very gross instance of misapplied science. There is certainly no proof that the atmosphere reaches so high; neither is it reasonable to suppose, that the excessive rarefaction of the air at such immense heights, would be favourable to the existence of such phenomena in that region; nor would it be consistent with some of the most probable opinions that have been advanced respecting the cause of this meteor, without we admit the opinion of La Cepede on this subject, who supposed the auroræ boreales to be electric meteors, flashing beyond the limits of the atmosphere. Again, if the height at which these meteors generally appear be so greatly elevated above the earth, there seems to be no reason why they should not be visible more universally, and oftener towards the equator: nevertheless, the extent of the distance at which they become visible in common is very much circumscribed; and there are innumerable instances of a distinctly marked aurora not having been discernible at different places near to each other, although, at the same time, the temperature and serenity of the atmosphere was uniformly the same in both. Those auroræ that were observed in Denmark and at Berlin could not be discerned at Breslaw. The auroræ that were visible at Toulouse, towards the end of summer 1730, were not seen at Paris; and, on the contrary, an aurora that was seen at Paris, in the beginning of summer in the same year, was not apparent at Toulouse. But even very bright auroræ have not been visible in places only twenty miles distant. In 1719, an aurora was discerned at Vincennes on the 22d of February, at Montauban on the 25th March, and at Paris on the 30th of the same month; but in each of these instances its appearance varied as to time, though these situations are at no great distance from each other. According to Perè Cotte, the aurora of 1769, on January 5, was observed on the same day at Paris and Pensylvania, and that one which appeared on the 17th September 1770 was seen at the same time at Paris and Pekin: but perhaps there is not another instance of this meteor heving been discerned at the same time in places so distant; and, as the same author very candidly observes, it varies often even in places adjoining: besides, in these two last-mentioned instances, it is impossible that the same appearances should take place at the same time in the atmosphere over places situated at such an immense distance, in opposite quarters of the globe; we rather imagine, that it shows a general disposition in the atmosphere to generate the same kind of meteor every where. In the month of October 1804, there were frequent auroræ seen in the county of Aberdeen, though any streamers that were visible at Edinburgh, or even much nearer to the confines of the above-mentioned county, were extremely faint, and by no means corresponding in point of time.

The following is an extract from a letter, giving a description of an aurora which was seen in Aberdeenshire at that time; and as it comes from a person very accurate in his observations, and unprejudiced by any opinion on the subject, his communication is therefore more valuable. The letter is dated October 13. 1804.

" It was about six o'clock of the evening of the 12th instant, the moon having just completed her 9th day, the sky being cloudless, when I perceived some symptoms of the approaching radiance that was soon to deluge the sky with a flood of brightness: for some time, I was amused with the fantastic forms assumed by the faint flashes of the light. By degrees, they grew more vivid, and darted out in all direcrections: sometimes an immense body of light illuminated the whole northern division of the sky; immediately this disappeared, and another equally bright and equally extensive succeeded: sometimes the light seemed to be in one undivided stream; in an instant it vanished into innumerable rays of wonderful fineness, thinner than hairs; you would have thought these minute rays again united into larger beams, distinct from each other, but apparently uniform in their surface, and so condensed, that the smaller divisions were imperceptible; at last almost the whole horizon was overspread with light: soon after this the appearances became grander than even imagination can paint: the light burst out in all directions with inconceivable rapidity, and in an infinite variety of forms; at one spot, almost directly vertical to where I stood, the light appeared in all the colours of the rainbow: I could distinctly and clearly observe red, purple, blue, green, yellow and orange, some of them very bright, others somewhat fainter. It was almost awful, the blaze was so universal, and shot so rapidly athwart the whole plain of ether. The moon now began to descend in a purple vapour, and, immediately before she disappeared, the flame swept over the whole sky with renewed splendour. After I lost sight of the moon, which was about half past ten o'clock, the luminous appearances became less grand and less extensive, but they were by no means extinguished. I am sure of this fine sight having lasted at least seven hours. I watched till two o'clock; when I went into the house, I found my hat and great coat white with hoarfrost; the fields were overspread with hoarfrost next morning; and the trees were almost universally stripped of their leaves. On the evening of that day, it began to thaw; and about seven o'clock it began to rain violently. Before midnight it was a perfect hurricane."

The appearances which attended this meteor, the vertical situation of its illuminating radii, together with the moist state of the atmosphere, and the subsequent storm, tend to prove, that in this instance at least the aurora has depended on local causes, and by no means reached to an extraordinary height in the air.

M. Miraldi relates, that he saw an aurora "between two strata of clouds, the first stratum more elevated, which obscured the sky, and which the aurora illuminated; the other stratum below was not so extensive:" And he concludes, that "the matter of which the phenomenon is formed, is not so highly elevated in the atmosphere; that there are clouds still higher than it; and the knowledge of this fact must be of importance in explaining its nature." This observation of Miraldi has been confirmed in this country; and likewise those which Muschenbroeck saw in 1728 and 1733 were situated amongst the clouds, and very near to the earth. If the boreal regions be the only source of this meteor, it appears rather difficult to bring forward any feasible reason to explain why the northern lights, which were so universally apparent in 1770, should be discernible several hours earlier in the western part of Europe than in places more to the northward; and were this meteor so highly elevated in the atmosphere as has been imagined, it is impossible to conceive how any sound could be heard from that height, without a most forcible concussion of the air; nor could the refraction of the coloured rays, which this meteor frequently evolves, be perceived at the earth's surface: indeed, to produce these effects, the aurora must be only at a very short way above the spectator. Again, it is not necessary that the atmosphere should be illuminated at a great height, to cause it be visible at a considerable distance; it is known, that the open fires employed in iron-works, and other manufactories, illumine a space in the air, that can be discerned fifty and even eighty miles distant; but this is only observed to take place when the lower part of the atmosphere is loaded with vapour. Mr Boyle was likewise informed by a correspondent, that in the course of a journey over the Alps, he frequently saw a flashing of light through the different strata of clouds as he passed them during night; and in a note to Colonel Capper's treatise on winds, he observes, that in the month of April and May, forty or fifty miles inland, and even on the coast of Coromandel itself, almost every evening incessant flashes of lightning were perceived at a great distance westward over the Balliagat mountains. It is likewise to be observed, that the auroræ are most prevalent in that season of the year when the lower air is most impregnated with vesicular vapour.

The cause of the aurora borealis has not yet been determined with any tolerable degree of certainty. Many opinions have been brought forward on the subject; but all of them seem liable to unanswerable objections. At present, electricity is regarded most generally as being the cause of this phenomenon; though the effects of magnetism in this respect are also supported by philosophers of the most respectable talents. M. de Mairan has likewise attempted to explain the appearance of the meteor in question, as depending on certain conditions of the sun's atmosphere, or, as he calls it, the zodiacal lights; but the immense distance between this globe and the sun, renders it extremely improbable that there ever takes place an intermixture of the atmosphere of these planets; or, even allowing that an intermixture does sometimes occur, how does this theory reconcile the appearance of the northern lights, with that season of the year when the northern hemisphere is most declined from the sun? The cause of this meteor has also been assigned to the combustion of hydrogen gas in the atmosphere, and to the inflammation of other combustible matters; but the existence of any such matters, in sufficient abundance to produce all the phenomena of the aurora borealis, remains to be proved. Besides, the light emitted by this meteor is totally different from that given out by any of these substances in a state of combustion.

Dr Halley, and more lately Mr Dalton, have brought forward many ingenious arguments to show that the aurora depends on the quantity of magnetic fluid existing in the atmosphere; the polarity of magnets having been observed to be disturbed during the appearance of that meteor. But Pere Cotte denies that this occurrence uniformly takes place on such occasions; and as the same circumstance is perceived to happen when the atmosphere is in a positive state of electricity, the theory itself therefore becomes in the highest degree questionable. Mr Dalton has collected the most extensive series of observations respecting the appearance of the auroræ at different periods of the moon's age: the following is accordingly a table of the result:

Days past change and full.	Number of observations.	Days past change and full.	Number of observations.
0	14	8	18
1	25	9	23
2	21	10	15
3	20	11	6
4	19	12	10
5	20	13	13
6	15	14	9
7	21		12

It has not yet been determined in what manner electricity produces this phenomenon. Beccaria having perceived, that electricity gives polarity to magnets, and as M. Bergman afterwards found, that a magnetic needle was disturbed during an high aurora borealis, it has been concluded, that this meteor is merely occasioned by the circulation of the electric fluid through the atmosphere; but as the auroræ, whenever they have been observed, always shoot in a direction from the poles to the zenith, it affords a strong presumption against the correctness of this opinion; for, if the circulation of the electric fluid takes place in the manner Beccaria supposes, we should in that case rather expect to see the auroræ darting in a direction from the equator towards the poles. Mr Canton, who also argues for the electrical origin of the northern lights, puts the following question: "May not air suddenly rarefied, give electric fire to, and may not air suddenly condensed, receive electric fire from, clouds and vapours passing through it?" and, "Is not the aurora borealis the flashing of electric fire from positive towards negative clouds, at a great distance through the upper part of the atmosphere, where the resistance is least?" But it seems more probable, that a circulation of the electric fluid in this way, must rather tend to produce thunder than any other meteor. This ingenious philosopher has likewise attempted to show, that the atmosphere contains but little electricity during the appearance of the northern lights; and it is certainly very much to be desired, that those who support this theory would point out the precise state of the atmosphere in regard to this fluid during the existence of the aurora borealis; different observers having found it in various states of electricity at these periods.

Were Mr Canton's questions to be answered in the affirmative, the auroræ should be observed to dart out in all directions; neither would this phenomenon be limited to particular latitudes and places: they should be also more common in summer than in winter. But, after all, the greatest proof of the identity of the auroræ and electricity, is from the similarity of the electrical light in penetrating a vacuum, to the appearance of the streamers, as they shoot through the aërial expanse. Electricity is said to be most abundant in the atmosphere during those nights when the auroræ are most vivid; but Pere Cotte could not ascertain this to be the case at Montmorenci, although he gave every attention to the subject. But although it were uniformly so, the fact would not be at all conclusive in regard to the theory; electricity being perceived to abound in the atmosphere, when no such appearance takes place. But if the cause of the aurora borealis were owing to the abundance of electricity in the higher regions of the atmosphere being more copious near the poles, and imagined to flow towards the equator, for the purpose of supplying the supposed waste of that fluid within the tropics; they should in that case be discernible every where in the intermediate space; they would then constantly appear during cold weather; and be at all times visible at night on the top of every high mountain.

From the relations of voyages to the frozen sea, it seems to be uniformly observed, that the large masses of ice found there have the property of reflecting a bluish colour, in like manner as the snow. Frederic Mærtens says, that in the neighbourhood of Spitzbergen, when the sun begins to throw out a very faint light, the snow over the tops of the mountains, which are in 80° N. lat. appear extremely luminous, and the points of ice on the rocks look as if on fire. The light thus emitted, dazzles the eyes of the spectators. Likewise, along the coasts of that sea, there is a shining white light in the atmosphere, immediately over that part of the ocean where it freezes; but beyond that limit, the air shows a very dark blue. The former space has circles in it like rainbows; and halos of the sun and moon are more frequently observed there, which are supposed to be occasioned by the reflection of light from the frozen particles with which the atmosphere abounds. Lord Mulgrave observed this appearance, and found, that a brightness near the horizon always indicated the approach of ice; this is well known to every one who has navigated those seas, and is called by the sailors the Ice Blink. There are many circumstances connected with the existence of electricity in vapour, that must be determined before a full explanation of any electrical phenomena occurring in the open air can be satisfactorily accounted for. This fluid is more readily excited from every matter during an intense frost, than at any other season. Its excitement from the atmosphere is probably owing to the change which vapour undergoes in respect to its power of conducting the electric fluid; ice being a worse conductor of electricity than any other condition of water.

The inhabitants of high northern climates observe, that the aurora is strongest when a sudden thaw succeeds severe cold weather. At a temperature below 32°, air will therefore apparently contain more electricity than in any other state, and of which it will be readily deprived, on any remarkable change taking place in its temperature, or upon the occurrence of any conducting medium, as vapour. Perhaps in this way electricity may act a very powerful part in occasioning the appearance of the northern lights during a thaw, as formerly mentioned.

The Abbé Hell, astronomer royal to the imperial court of Germany, supposes, that the aurora borealis is of a similar nature with mock suns, halos, &c. and that they are occasioned by the congealed vapours in the atmosphere sometimes reflecting the light of the sun, sometimes that of the moon, and occasionally both at one time. These conclusions were inferred from observations made on the nature of the northern lights, when he remained in Norway expecting a transit of Venus.

Whatever may be the immediate cause of the aurora borealis, it seems evidently connected with the condensation of vapour from the air. During their appearance, there always takes place a copious precipitation of dew, or hoar-frost. The auroræ are seldom apparent during hot weather or in tropical countries, except in the vicinity of mountains; probably because in the former circumstances the vapour contained in the atmosphere is usually in its most elastic state, and its lower strata comparatively more dry. For it has been observed, that this meteor is most distinct and frequent in those latitudes wherein the vesicular vapour hangs near to the earth's surface, and when its devaporation and precipitation gradually take place; being most prevalent in autumn, and in the early part of the evening, when the dew falls more plentifully than at any other season of the year, or time of the night. According to observation, Pere Cotte found the aurora borealis appear more frequently in March, April, September, and October. By these circumstances, together with what has been already remarked respecting the iridescent colours, and sound emitted by the northern lights, it is rendered probable, that their situation is but a little way elevated above the surface of the earth.

The auroræ boreales have been observed most frequently to occur about the season of bad weather, and have therefore been supposed to prognosticate rain and high winds. Mr Winn ascertained, that in 23 instances, he never missed to find a hard gale from the south or southeast: he made these observations in the English Channel. When the auroræ are very luminous, the gale may be expected within 24 hours, and of short duration. If the colour of the aurora be dull or dark yellow, the gale will be longer in coming on, less violent, but of longer continuance. Indeed, it would seem, that almost every luminous meteor appears as the harbinger of bad weather. If the opinion that has been advanced, respecting the dependence of the northern lights on the existence of vesicular vapour in the atmosphere, be confirmed, an unusually moist state of the air may therefore be always presumed from their appearance, and, consequently, changes of weather corresponding to this condition may be expected.

It is the opinion of Abbé Hell, that every aurora borealis is succeeded by unusually cold and rainy weather, which comes on always about forty days after its appearance. In the course of ten years, Peré Cotte found, after eighty-six auroræ, that forty of them were followed by cold, rainy, and windy weather, from five to six weeks after; but there was nothing determinate succeeded the other forty-six: therefore, he says, the Abbé's opinion is in this instance doubtful. At the same time, though general observation in Britain, respecting the prognostication by the aurora borealis, be rather in accord with those of Mr Winn, nevertheless, a succession for several nights of the most vivid auroræ, early in autumn 1805, not far from the foot of the Grampian mountains, preceded an unusually dry mild season. Mr Dalton found, that the auroræ boreales are more frequently followed by fair weather in summer, than in winter: the distinction, though not considerable, inclines him to regard this meteor as a sign of fair weather.

SECT. V.

OF PHOSPHORESCENT METEORS.

Of the Ignis Fatuus.

THE only phosphorescent meteor which is generally known, is called the *ignis fatuus,* Will with a Wisp, or Feux Folets by the French: it is understood to be occasioned by the combustion of hydrogenated phosphoric gas, and is imagined to be unconnected with the causes producing other luminous meteors. It appears most commonly in still warm evenings, and in the vicinity of marshes: it is therefore said to be frequent in the fenny counties of England: and there are districts in every climate, where its appearance is most common. Several of them are usually seen at a time; and their appearance is that of a small pale-coloured flame issuing from the soil. The late Dr Darwin, who had frequently occasion to be abroad in the country in the evenings at every season of the year, never had the luck to meet with this meteor: the same remark has been made by others, whose opportunities of observation were perhaps equally good; nevertheless, the existence of it in this country is established by repeated observations. In Palestine, the *ignis fatuus* is said to occur as a shining star on the ground. Richard mentions an instance where a person got quite near to one of these lights; he saw it distinctly burning with a lambent blue flame, and it produced a peculiar noise, something like the burning of charcoal. In the plain country around Bologna, it is frequently seen during winter; and in the same season in Spain it frequently darts up even through the snow,—a circumstance which has been supposed to prove that they are compounded of other matters than those we have mentioned. This meteor has been said to move on before travellers, and thus lead them into perilous situations; at other times, it has appeared to follow them: it frequently seems also to become suddenly extinguished, and immediately to rekindle; these appearances are entirely occasioned by the great fluidity of the atmosphere, whereby it is put into motion by the slightest impulse. It may also become suddenly extinct by the exhaustion of the matter with which it is supplied, and reluminated by the calmness of the weather allowing it again to collect.

The cause of the *ignis fatuus* has been supposed to arise, in the first place, from the decomposition of water in the soil, whereby a quantity of hydrogen gas is disengaged; this gas having the property of dissolving phosphorus, a matter which abounds in the decaying remains of animals and vegetables. These substances being found in abundance in places where this meteor is frequent, it has therefore been conjectured, that the phosphorus, being in solution with the hydrogen gas, takes fire on its immediate communication with the air.

The following narrative by Richard, giving the account of an appearance probably depending on a cause similar to the above, may serve to illustrate the doctrine entertained respecting this species of meteor.

On the morning of the 26th July 1757, a master mason, with two workmen, went to the house of a gentleman at Paris, for the purpose of repairing the outlet of the privy, which had become choaked. On lifting a stone, which exactly shut up the gutter, they immediately perceived a blue vapour issuing from it: the light which the workmen had with them was placed at the distance of at least five feet from the opening; they were unable to discern any thing within the gutter, on account of an acrid vapour which filled the whole space, and rose even above its level; they then took a bit of burning paper to enable them to examine what was wrong, and threw into the place; this set fire to the vapour, and there immediately issued a flame of such force, that it burst open a trap door opposite to where the masons had made the opening, and darted to the height of eighteen feet within the court: it continued for the space of half an hour, sometimes becoming less strong, at other times renewing the conflagration with redoubled energy; the flame was of a blue colour, and it produced a noise like that of charcoal burning in a smith's forge.

SECT. VI.

OF STONES FALLEN FROM THE ATMOSPHERE, CALLED METEORIC OR THUNDER-STONES.

From the earliest records of philosophical observation, mention is made of certain stones having been seen to fall from the atmosphere. These are generally known by the name of thunder-stones, and have at different times been supposed to possess many specific virtues in the cure of diseases, and for the prevention of general calamities. This opinion is not confined within a limited circle, nor peculiar to the inhabitants of Europe; those of China, and the native Americans, having been found to entertain similar ideas.

It was not, however, till lately, that the enlightened part of mankind were agreed respecting the real nature of these stones, many having persisted, that their supposed descent from the atmosphere must be esteemed as a deception or mistake, and that they differ in no respect from other stones that are common every where. But the great progress in the improvement of every branch of chemical science has likewise tended to elucidate the properties of these matters, and has assisted in settling every dispute respecting their origin.

Wherever these stones have been discovered, they show unequivocal marks of having been exposed to a very powerful degree of heat. By examining them, they are found to correspond in their properties, both as a component mass, and in their individual principles. In many particulars, they differ from every other stony substance. There are numerous well-authenticated instances of their fall from the atmosphere, affirmed by such proofs, that there does not remain a doubt of the fact. Their fall is always accompanied with a loud whizzing noise in the air, and a storm of lightning and thunder. Stones from the weight of an ounce or two to that of several tons have fallen in this manner. It has been likewise said, that the arrow-heads of the Canadian Americans are formed of a stone that has had a similar origin, and that they have been reduced into a particular shape, by grinding the one against the other. Other matters have likewise been known to fall from the atmosphere upon the earth, as iron, chalk, ashes, &c.

Klaproth has shown, that native iron never contains nickel; and, as this metal is found in the large masses of iron that have been found in Siberia and in America, it is therefore generally supposed, that they must have also originated in this way. This opinion is rendered still more probable, by other authentic instances, where small masses of iron have been seen actually falling from the atmosphere. Stones of this description are found to be excessively hard; and Abbé Richard seems to think, that there is evidence that they were employed, before the discovery of iron, for many purposes for which this metal is now used. These stones have been always found of a peculiar shape, being somewhat oblong. In the act of falling, they are always observed excessively hot; and in their descent through the air, they have all the appearances of a fire-ball, and emit a strong sulphury smell. When broken, they are not uniform in their composition; their substance being made up of metallic grains, a greyish earth-like matter, a portion of pyrites, with some substances of a spheroidical form, opaque in their colour; and they feebly emit sparks when struck by steel. These stony substances have been repeatedly analyzed by the most accurate experimentalists of the present day; and in their composition, they have been found to differ from every other matter. They uniformly contain siliceous earth, magnesia, oxide of iron, nickel, sulphur, lime; and chromium has been detected in those which fell a few years ago in France: but these matters are not combined in the same proportion in every instance. Their external colour is usually dark brown, or black.

This meteor is not particularly mentioned by Aristotle; but Livy and Pliny also give an account of two different instances of such an oc-currence; and the following quotation from an author of equal credit to either of them, and who was probably an eye-witness of what he relates, will serve to show how early this meteor was observed: "Per id tempus fere Cæsaris exercitui, res accidit incredibilis auditu, namque virgiliarum signo confecto, circiter vigilia secunda noctis, nimbus cum saxea grandine subito est exortus ingens." Indeed, in every country, there are either traditionary or written records of such a phenomenon. Pareus relates a similar fact to that mentioned by Hirtius, and which must have happened about the period in which he lived. "Sugoliæ ad Hungariæ fines, saxum e cœlo cum ingente frigore lapsum est 7mo die Septembris 1514, ponderis ducentarum quinquaginta librarum: id cives ingente catena ferrea trajectum ex medio civitatis templo pendere voluerunt, viatoribusque per regionem suam divitibus magni miracoli loco monstrari."—Pareus, De Monst. Cœlest.

In 1510, there fell in the Milanese, in a valley near the Idda, about two hundred stones, of an iron colour, with a strong sulphureous smell, and possessed of an extraordinary degree of hardness. It was presumed at the time, that these stones must have been ejected from some volcanic crater, which had afterwards immediately closed.

In the church of Ensisheim, in Alsace, there is preserved a large blackish-coloured round stone, which bears evident marks of having been in the fire, and to have split in its circumference into many bits. It is recorded, that this stone fell from the sky on the 7th November 1492, and weighs near three hundred pounds.

Gassendi relates, that about ten o'clock in the morning, 27th November 1637, the air being very calm, their fell upon Mount Vaisien, between the towns Guilaume and De Peine in Provence, a stone, seemingly on fire, surrounded with a luminous circle of different colours, which made it appear of about four feet diameter. It passed within a hundred paces of two men, who judged its height in the atmosphere to be about six toises. It caused a loud hissing sound in descending, and fell to the ground at a little distance from them, giving out a strong odour of burning sulphur; a great smoke arose from it when it had alighted, accompanied with explosions like the discharge of musketry. Several people were thereby attracted to the place; and they found, that it had sunk three feet into the earth, with an opening of about one foot in diameter. The snow was melted to the distance of five feet around the spot, and every thing in its immediate vicinity seemed to be parched and burnt. On digging, they discovered the stone, which is of a dark colour, of a metallic lustre, and weighs fifty pounds. It is kept at Aix in Provence. Paul Lucas mentions having seen one fall at Larissa in Macedonia, which weighed seventy-two pounds. It was surrounded by a cloud before it fell, and caused a very disagreeable alteration in the state of the atmosphere.

On the 3d and 4th of June 1731, at Lessay, near Coutance, the whole sky seemed on fire, from the horizon to the zenith; vivid flashes of lightning crossed through the air like a fire-work, and there fell, every where around, bits of metal, as if they had been melted: the horror occasioned by this phenomenon was greatly increased, by a most dreadful thunder storm that followed their precipitation; buildings were shaken by them, others thrown down, and many cattle were killed; there fell but a small quantity of rain, and none had fallen for some time before. There was also a stone of this description said to have fallen on the 5th April 1804, at Possil, in the neighbourhood of Glasgow; it passed some labourers in a field, who had their attention aroused by the great and uncommon noise in the atmosphere. There are also repeated instances of the same kind, given in the work of Julius Obsequens *de Prodigiis*, from the earliest period of the Roman history, down to the death of Cæsar; and similar meteors are occasionally noticed, in the writings of authors in the middle ages, down to the present æra: the former author, among many similar instances, particularly mentions an immense stone having fallen, during the consulate of C. Claudius Pulcher, and T. Sempronius Gracchus.

In addition to the above instances, the following table is subjoined, of the most remarkable occurrences of thunder-stones, taken from authentic records, and collected by M. Izarn, in his work called *Lythogenesie Atmospherique.*

Substances.	Places where they fell.	Period of their fall.	Testimony.
Shower of stones	At Rome	Under Tullius Hostilius	Livy.
Shower of stones	At Rome	Con. C. Martius & M. Torquatus	J. Obsequens.
Shower of iron	Lucania	Year before the defeat of Crassus	Pliny.
Shower of quicksilver	Italy		Dion.
A large stone	Near the river Negus, Thrace	2d year of the 78th Olympiad	Pliny.
Three large stones	In Thrace	Year before Jesus Christ, 452	Count Marcellus.
Shower of fire	Quesnoy	January 4. 1717	Geoffroy the younger.
Stone weighing 72 lbs	Larissa, Macedon	January 1706	Paul Lucas.
1200 stones, one of 120 lbs. and another of 60 lbs	Near Padua	1510	Carduy Varcit.
Another of 59 lbs	Vaisien, Provence	1627	Gassendi.
Shower of sand, 15 hours	In the Atlantic Ocean	April 6. 1719	Pere la Feuillée.
Shower of sulphur	Sodom and Gomorrah		Moses.
Rain of sulphur	Dutchy Mansfelt	1658	Spangenberg.
The same	Copenhagen	1646	Olaus Wurmius.
Shower of sulphur	Brunswick	1721	Siegesber.
Shower of viscid matter and unknown matter	Ireland	1695	Muschenbroeck.
Two large stones, 20 lbs. each	Leponas in Bresse	1753	La Lande.

Substances.	Places where they fell.	Period of their fall.	Testimony.
A stony mass	Niort, Normandy	1750	De la Lande.
A stone 7½ lbs	Luce in Le Maine	September 13. 1768	Bachily.
A stone	Aire in Artois	1768	Gaison de Boyaval.
A stone	Le Contentin	1768	Morand.
Great shower of stones	Near Agin	July 24. 1790	St Amand, and others.
Twelve stones	Sienna, Tuscany	1794	Earl of Bristol.
A large stone 56 lbs	Wold Cottage, Yorkshire	December 13 1795	Captain Topham.
A stone 20 lbs	Sall, Department Rhone	March 17. 1798	Lelievre et De Dree.
A stone 10 lbs	Portugal	February 19. 1796	Southey.
A shower of stones	Benares, East Indies	December 19. 1798	J. L. Williams, Esq.
A shower of stones	Planse near Tabor, Bohemia	July 3. 1753	Baron de Born.
A mass of iron, 70 cubic feet	America	April 5. 1800	Phil. Magazine.
A mass of iron, 14 quintals	Abakanhe, Siberia	Very old	Pallas, and others.
A shower of stones	Barbantan, near Roquefort	July 1789	Darcit the younger.
Large stones 260 lbs	Ensishiem, Rhine	November 17. 1492	Rutenshoen.
One stone 200 lbs. one 300 lbs	Verona	1762	Acad. de Bourdeaux.
A stone 20 lbs	Salls, near Ville Franche	March 12. 1798	De Dree.
Several stones from 10 to 17 lbs	Near Aigle, Normandy	April 26. 1803	Fourcroy.

Many ingenious hypotheses have been adduced in attempting to explain the origin of these stones, which hitherto remains involved in the most complete obscurity. About the commencement of the 18th century, it was strenuously denied, that such matters ever descended from the atmosphere; that their seeming fall is a deception, in consequence of the preference which electricity shews for such substances as those stones are composed of; and that they are merely metallic matters, heated by the electrical fluid during a thunder storm. But there does not exist any good reason why this opinion should be implicitly credited; for, independently of the undoubted evidence of those stones having been seen in the act of falling, no very great or unusual degree of attraction is known to exist between the electric fluid and the great proportion of matters which enter into the composition of thunder-stones.

Another opinion succeeded the above, and has prevailed with some celebrated men, even to the present time. They believe that these stony matters originate in the higher regions of the atmosphere itself. This hypothesis seems to have been supported by the late Sir William Hamilton; but it has been maintained all along without the aid of a single fact to render its accuracy even probable. No substance can exist in the atmosphere, merely in a state of mixture, whose specific gravity is greater than that fluid:

and allowing that the principles composing thunder-stones are not simple bodies, according to the doctrines of modern chemistry, no proof has been adduced to shew, that the component particles of the different stony and metallic matters, found in those substances, are of a specific gravity sufficient to render them buoyant in the air. It seems difficult to be accounted for how those matters get to the higher regions of the atmosphere; and that certain substances are only combined in the formation of meteoric stones, to the exclusion of all others; for it appears probable, that if this be the occasional origin of one or two earths and as many metals, that all matters of a similar kind will also be produced in the same manner. Again, this hypothesis does not explain the constant appearance of this stone having been exposed to an intense heat, it having been shewn, that the upper regions of the atmosphere are always at a temperature below the freezing point: neither, by the above opinion, can it be readily comprehended, how those stones should, in every instance, descend, as if propelled by an immense force, which is entirely different from the velocity which would be caused by their specific gravity alone. In the 45th volume of the Annales de Chimie, p. 62., there is an essay on this subject, by Eusebe Salverte, in which he attempts to do away the most forcible objections to the above-mentioned opinion. He remarks, that there is no substance so seldom found in stones ejected from volcanoes, as magnesia, if it be not native iron, or which is alloyed with nickel, according to the analysis of Vauquelin. He supposes, that the matters forming meteoric stones, have been previously volatilized by heat, in the interior of a volcano, and in this state, being dissolved in hydrogen gas, they ascend to the higher regions of the air. A process somewhat similar to this, he thinks, takes place in the dissolution of matters in general. He supposes the hydrogen compound in the higher regions, is occasionally set fire to by the power of electricity, as that fluid tends to an equilibrium between the earth and air: the metals and other matters held in solution by the gas, being in this manner revived and precipitated, coalesce into masses in their descent; and as they retain the heat occasioned by the combustion of the solvent, in this manner they constitute the whole phenomena. But most of the objections we have stated to the simple opinion, apply directly to this also. It has been already shewn, that there does not exist a proof of an isolated stratum of hydrogen gas in the atmosphere; nor would the quantities of the matters forming meteoric stones, which hydrogen is capable of dissolving, be sufficient to constitute their appearance; neither is there any proof, that any of the matters of which meteoric stones are found to consist, are soluble in hydrogen gas; and, on the other hand, were this really the manner in which these were generated, we should naturally expect to find them occasionally mixed with substances which are most soluble in that gas, and which abound most plentifully in situations pointed out by Salverte, as the primary source of the others.

The celebrated De la Lande entertains an opinion, that this meteor is produced from volcanoes in the moon: that during their eruption, stones, such as we have described, are projected upon the earth. This ingenious philosopher has collected many valuable observations in support of his theory, and, consequently, has not ventured to propagate it, without mature reflection and conviction of its accuracy; but nevertheless, it still appears liable to many unsurmountable objections. Thunder-stones have all the appearances of having been exposed to the action of volcanic fire, as no other natural degree of heat known seems sufficient to effect the changes upon them which they are perceived to have undergone. But whether they have been exposed to that power in volcanoes in the moon, or in those always open upon this globe, is a question of the greatest difficulty to determine. Allowing that the eruption of a lunar volcano has sufficient power to eject a mass of matter to such an height, that it would come within the sphere of the attraction of the earth's atmosphere, and that the increasing density of the latter augmented this force; should we not expect, that the meteor itself would be quite cool before it reaches the ground, in conquence of passing through an immense tract of cold air, as well in the atmosphere of the moon, if it possesses one, as in that of the earth? It may however be suggested in refutation of this objection, that the thunder-stones, by decomposing the atmosphere through which they pass, may be supplied with all that is necessary for keeping up their temperatures. To this it must however be observed, that the inflammable nature of these stones has not yet been discovered; on the contrary, the greatest proportion of their component principles have a very opposite property. At any rate, it is probable, that the great velocity of their course would entirely preclude any advantages that could be gathered from such an effect. Besides, it is necessary to determine with what probability we may conclude, that the component matters of thunder-stones do really exist in the moon. But matters have fallen from the atmosphere upon the earth, when it was impossible, from the moon's position with respect to this globe, that they could have originated in that planet; and the variety of matters which have fallen in this manner, likewise contradict this opinion. Julius Obsequens observes, that "anno urbis 643, in Vestinis per dies septem lapidibus testisque pluit;" and under the consulate of Quint. Metellus and Tullius Didius, "anno urbis 646, ludis in theatro creta condida pluit." For further illustrations of this kind, we refer to M. Izarn's table.

It is well known, that every substance detected in the analysis of these matters, abounds in the composition of this globe: if, therefore, so prodigious a force can be ascribed to lunar volcanoes, may it not be supposed, on equally good grounds, that terrestrial ones are possessed of as much power. All the component parts of thunder-stones have been met with in the vicinity of volcanic craters, in different parts of the globe. Though these have not been found in combination, this is perhaps in a great degree owing to the little progress that has been made in the investigation of matters ejected from them; but if thunder-stones are only thrown out during the most violent eruptions, it cannot be expected that those stones in its immediate vicinity will in general resemble them. Thunder-stones are always accompanied with a shining light, and they have been said to move along with many of the fire-balls that have occasionally appeared. If this should be found to be really the fact, it will go a great way in enabling us to detect their origin; for the most conspicuous of those balls of fire have been almost directly traced to the actual eruption of some volcanic mountain. The height at which fire-balls have appeared in the air, is also sufficient to account for the dejection of thunder-stones in places at a very great distance from their sources. Stones of this description were very frequently found in Greece about the time of the appearance of the island of Sanctorini, which is known to be of volcanic origin; and showers of sulphur, tuffa, ashes, and many other volcanic matters, have been found at an immense distance from the craters from whence they had been ejected; matters thrown out by Vesuvius having been found on the African coast, also to a great distance across the Adriatic and upper part of the Mediterranean Sea. We may therefore conclude from these circumstances, that although there is no positive demonstration of the truth of the volcanic origin of thunder-stones, the opinion carries the force of probability in its favour; while any objections that have been opposed to it, cannot be regarded as completely irrefragable; and it certainly accounts more satisfactorily for all the phenomena, than any other hypothesis that has been adduced in explanation of their origin.

SECT. VII.

OF PROGNOSTICS.

On considering the foregoing observations respecting the physical properties of the atmosphere, it becomes evident that the information we acquire of this subject, will be of importance in the purposes of life, nearly in proportion to the knowledge we thereby obtain of predicting the various changes of the weather. This is an investigation that has deservedly occupied the attention of the ingenious in every age: agriculture, navigation, and many of the most useful branches of practical science, depend on the state of the atmosphere in their various processes. Our knowledge of the properties of the atmosphere would therefore become of the highest utility to mankind, could the varieties of season, or recurrence of sudden changes of weather, be readily prognosticated. But this investigation is so intimately connected with circumstances which influence different climates, that a general table of prognostics can only be completed by the united labours and experience of the learned in every country. Hitherto, the improvement that has been made in this useful branch of natural knowledge, is very trifling; and although a variety of tolerably perfect instruments have been contrived, by which the properties of the atmosphere have been more fully ascertained, and the changes about to occur in it have been sometimes predicted by their means, still it is much to be regretted, that they do not enable us to foretell the particular states of weather about to ensue. Therefore, few material advances have been made in addition to those handed down to us by the earliest writers on the subject.

Our knowledge of prognostics is collected from the influence of the atmosphere on the barometer, thermometer and hygrometer, together with the united experience of circumstances which have preceded a similitude of different seasons, or changes of the weather. The latter circumstances are principally acquired by observations on the atmosphere itself, its effects on living matters, or by the changes it produces on other natural bodies; and to these must be added the force of planetary influence, being the experience of certain changes taking place in the atmosphere, according to the position of the earth in respect to the sun and moon.

With respect to the method of prognosticating changes of the atmosphere by means of the indications afforded by instruments, it is extremely unfortunate, that, in this instance, the changes have generally commenced before any alteration is indicated by them; and even then they are not always to be relied on; as similar indications precede the occurrence of very opposite states of weather. The barometer is the instrument usually attended to as a weather-glass; from whose alterations, we acquire the most certain information regarding the changes in the condition of the atmosphere; the temperature and humidity of the air, as indicated by the thermometer and hygrometer, having always a direct influence in varying the density of the atmosphere; the barometer therefore assists us in forming an opinion of the probable occurrence of these particular conditions. The mercury in the barometer commonly rises during fair weather: it generally falls before rain: it likewise falls before violent winds, and sinks unusually low before a heavy gale: it rises rapidly as it blows over; and it sinks lower if the wind has been accompanied by rain. It is highest during an east or north-east wind: in frost the mercury ascends, and if it rises during open weather, frost may be expected: if it ascends during rain, and continues to rise for two or three days, long fair weather may be expected to succeed. In like manner, when it falls suddenly during fair weather, much rain generally follows. The mercury remaining stationary, foretells a continuance of the same sort of weather. When the mercury in the tube is concave on its surface, it affords a sign that it is sinking: if the surface is convex, it indicates an opposite tendency. When the mercury in the barometer sinks a great space suddenly, it foretells a hurricane or earthquake. Mr Dalton observed, that when the barometer is near the high extreme for the season of the year, there is very little probability of immediate rain. When the barometer is low for the season, there is seldom a great weight of rain, though a fair day in such a case is rare: the weather at such times is generally short, heavy, and interrupted with sudden showers, and squalls of wind from the south-west, west, or north-west. When the appearances of the sky are very promising for fair weather, and the barometer low, a change of weather may be expected soon to happen. Very dense and dark clouds pass over without rain when the barometer is high; whereas, when the barometer is low, it sometimes rains almost without any appearance of clouds. Thunder is almost always preceded by hot weather, and followed by cold and showery weather. A sudden and extreme change of the temperature of the atmosphere, either from heat to cold, or from cold to heat, is generally followed by rain within twenty-four hours. This observation was made by Pliny: he says, "Tradunt enim eundem Democritum metente fratri ejus Dumaso ardentissimo æstu orassi, ut reliqua segete parcerit, raperetque desecta sub tectum, paucis mox horis sævo imbre vaticinatione approbata." M. Changuex has also made us acquainted with the following rules: When there are two different currents of air at the same time, if the higher one has a direction from the north, and that next the earth's surface be from the south, sometimes rain takes place, although the mercury in the barometer should stand high; but if, on the contrary, the south wind be highest, and that from the north nearest the earth, it never rains, although the barometer should stand very low. When the mercury rises much, and continues to ascend slowly, it foretells the continuance of fine weather; when it descends much, but slowly, bad or unsettled weather is indicated. When the barometer rises rapidly, it shews that the weather, whatever it is, will be of short duration; and when it sinks much, it prognosticates an opposite effect. When the temperature of the air is great, the descent of the barometer predicts a thunder storm: If the barometer rises in winter, it announces frost; if it then sinks somewhat, a thaw may be expected to follow; and if it rises during the thaw, it predicts a fall of snow.

M. Saussure, in his Essay on the Hygrometer, remarked, that during fair weather, the transparency of the air is less, while a great clearness of the air indicates rain: thus, distant objects seem nearer, and ships appear higher in the water, and more distinct before rain.

Dr Kirwan has with much assiduity cultivated this branch of knowledge, and has afforded us the following result of his observations, whereby we are enabled to form a probable conjecture of the state of the weather in the immediate succeeding season. 1st, When there has been no storm before or after the vernal equinox, the ensuing summer is usually dry at least five times in six; 2dly, When a storm occurs from an easterly point, either on the 19th, 20th, or 21st of May, the succeeding summer is dry four times out of five; 3dly, That when a storm arises on the 25th, 26th, or 27th of March, and not before in any point, the succeeding summer is generally dry four times in five; 4thly, If there be a storm at south-west, or west south-west, on the 19th, 20th, 21st, or 23d of March, the succeeding summer is generally wet five times in six. These observations were made on the climate of Ireland; but, in consequence of the corresponding changeableness of the weather in Britain, it is probable, that they may be applicable to both countries. If the 15th of July, the anniversary of St Swinthin, be fair or rainy, it forbodes a continuance of similar weather for the next succeeding six weeks,—generally for the remainder of the season. When the winter has been rainy, the following spring and summer are usually found to be cold and late. If May has been rainy, September is generally found to be dry. If Candlemas be dry, the following spring and summer may be expected to be dry and warm. Rainy weather generally follows within twenty-four hours after the flashing of lightning in the atmosphere, during serene weather. High winds and other changes have been said to follow the appearance of the auroræ boreales, from the days of Aristotle to the present time; but according to Mr Dalton, this meteor announces fair weather. After the appearance of 227 auroræ observed at Kendal and Keswick, 88 of the succeeding days were wet, and 139 fair,—an opinion which seems rather confirmed by the observations of Pere Cotte. By a table he has drawn up from the experience of twelve years, it appears, that fair weather precedes and follows the auroræ boreales oftener than any other temperature; that cold weather predominates oftener than warmth before and after this meteor; that it is oftener followed by rain, snow, and mist, than preceded by such weather: from whence it may be concluded, that these are a consequence of this phenomenon; though the difference is not so great as to establish this with precision. He did not find, by the above observations, that the auroræ boreales have an influence in regard to the wind, as it continued to blow, both before and after their appearance, from the same point.

Halos, parhelia, and St Helmo's fire, have been already mentioned, as being the forerunners of storms of wind and bad weather in the South Sea, and in the Mediterranean: in the climate of Britain, their appearance is usually followed by rain; sometimes they are succeeded, too, by dry weather. Falling stars are noticed by Virgil as the precursors of high winds. The more elevated the rays of the setting sun appear, the sooner will a change of weather take place: if the rays are red, as well as the body of the planet itself, it indicates wind. "Cœruleus pluviam denuntiat igneus euros." When the sun's rays appear rather of a purple hue, with greenish streaks, it indicates cold, and so much the more intense, as the greenish colour is more deep. When the sun appears dim at rising, or is obscured by thick clouds at setting, and especially if the sky is reddish in the east, it indicates rain shortly to follow. The sun rising pale, or appearing larger than usual, and especially if accompanied with parhelia, is regarded as the forerunner of storms of wind. If the moon first appears of a dead pale colour, and if the points or horns are blunt, it indicates rain; but when that planet seems of a larger size, and the colour approaching nearer to a red, with acuminated points, it forebodes wind; and when the colour is natural, with points sharp, it indicates cold weather, if in winter, but a continuance of fair weather in the summer.

According to the Shepherd of Banbury's observations, if the ten last days of February and the ten first of March are rainy, the spring and summer will be so likewise. It is always at this period of the year the droughts commence.

If the first days of November are almost all warm and rainy, January and February will probably be cold, more especially if the preceding summer has not been dry. If there occur frost and snow in October or November, in that case, the weather will be probably mild and clear in January and February. The sun rising red, announces wind and rain : if covered with clouds which gradually dissipate, it is a certain sign of fair weather. Clouds piled upon each other in the form of huge rocks, forebode great rain ; and little clouds collecting into larger masses, foretell the same occurrence : but large clouds becoming less, promise fine weather. When a south wind has prevailed for two or three days in summer, a great heat generally succeeds. When the clouds appear white on the top, and darker round the edges, storms and rain immediately follow. If two parallel clouds form, the one to the right, the other to the left, it is time to take immediate shelter. Mists on the low grounds, which disappear as the sun rises, afford a sign of dry weather ; but mists covering the tops of the hills, forebode rain the day following. A general mist before sun-rise, about full moon, is a sign of fine weather ; but a similar mist at sunrise about new moon, prognosticates rainy weather about the decline. A general mist before sun-rise, at the wane of the moon, is a sign of rain about the change. Vapour arising from lakes, and becoming visible, is held to be a sure sign of rain. Sudden rains are rarely of long duration; but when the atmosphere becomes insensibly obscured, the rain usually lasts six hours. The rain coming from the south, with a high wind, which falls after some hours, while the rain continues, it is probable that it will last twelve hours or more, and that it will not cease but by a north wind: it is seldom that such rains last longer than twelve hours, or return oftener than once a-year. If the rain begins an hour or two before sun-rise, it may be relied on that the weather will clear up before noon, and will remain fine till the evening; but if it does not come on till an hour or two after sun-rise, it will probably rain all day, at least if no rainbow is apparent. In the course of eight years, the wind blows as often from the south-west as from the north-east; so there is a like number of dry and wet years. If the wind changing to north-east, continues two days, not returning the third day to the south with rain, it may be concluded, that it will remain north-east with fine weather, then it will turn to the south. If it again quits the south for the north-east, with rain, and if it fixes in the north-east for two days without rain, or changes to the south without rain the third day, it is probable, that it will remain north-east for two or three months. After two months, during the time the north wind decreases, if a south wind supervenes, there commonly follow three or four days of good weather, succeeded by rain, at least if the wind does not shift to the north; in that case, the fine weather continues. If after two or three days without rain the wind becomes south, after turning to the north with rain, and returns south at the end of two days, varying in this way two or three times, then it may blow for two or three months from the south or south-west. Eight days of fine weather, with the occurrence of a south-west wind, are generally followed by great drought, especially if much rain has previously fallen from this point. When a cloud is seen moving in a direction different from the current of wind, it may be expected, that the wind will assume the direction of the clouds. When it clears up during night, fair weather is not to be looked for.

A rainy autumn, followed by a mild winter, are always succeeded by a cold dry spring. If the winter be dry, the spring will be wet. A serene autumn commonly follows a moist spring and summer.

When the leaves are long of falling in autumn, and when there remains a great quantity of berries on the white thorn, or hips upon the wild rose, a severe winter is announced, as these show that the summer has been wet.

Violent hurricanes or falls of rain produce a kind of crisis in the atmosphere, and after them, the weather generally becomes settled, whether good or bad.

M. de Saussure says, he never found it miss raining after the appearance of a cloud which reflected a portion of the primitive rays of light. He gives an instance where he was warned by this prognostic to take shelter, even when the sky continued fine, but which was almost immediately after agitated with a severe storm of wind and rain.

Animals often betray signs of great distress before approaching bad weather, especially high winds and thunder. Domestic cattle seek home, refuse to eat, and appear to look out for shelter. Insects, and many other animals, show forcible marks of their sensibility of any great change: thus, worms crawl more about than usual, flies are troublesome, and bees keep near to their hives, before rain. Spiders' webs being more abundant in the air than usual, bees found at a great distance from their hives, and returning late, and the lark rising earlier and continuing his song longer, are certain signs of fine dry weather.

The pains of rheumatism and of old wounds recur commonly before cold and rain, and then, also, the corns on the feet feel troublesome. In the same way, the cords of stringed musical instruments frequently snap, in consequence of their shortening by imbibing vapour from the atmosphere.

Birds of passage leaving their summer residence at an earlier period than usual, is assumed as a prediction of a severe ensuing winter. Birds keep near to the ground before a storm; and when the weather promises to continue fine, birds of prey mount high in the air. Before a storm, some kinds of water-fowl emit loud screams, dipping frequently under water, and are never seen at a distance from shore. It has likewise been observed, that when sheep begin to copulate early in the season, the temperature of the ensuing summer is usually mild and dry; but when this process commences with them late in the season, a backward spring and summer may be looked for. Aristotle remarked in regard to cattle, that "cum plures gravidæ sunt, et facile initum patiuntur, nimirum pro signo imbrium accipitur." Domestic and other fowls are observed to pick themselves, and annoint their feathers, by squeezing the follicle in their rumps, spreading the oil with their bills, previous to rain.

Man does not feel any regular warning of the approaching changes of the weather. There are some persons who experience great anxiety and distress before thunder, or during any remarkable change of the electrical state of the air. Particular winds, too, affect people of peculiar constitutions; and others, like Lord Verulam, fall into syncope on the occurrence of an eclipse. Pliny concludes his chapter on prognostics with the following curious observation: "Necnon et in conviviis mensisque nostris, vasa quibus esculentum additur, sudorum repositoriis linquentia, diras tempestates prænuntiant."

Plants give signs also from which some prognostic of the weather may be assumed; before rain and high winds their leaves and flowers are never so fully expanded as during fine weather; some substances become more bulky before wet weather, and in this way wooden work often acquires the bulk it had shrunk during drought.

It has been supposed of late, that certain years correspond with others recurring at a distant period: thus, Toaldo and others imagine, that these agree in temperature, humidity, &c. This similitude of seasons is imputed to the influence of the moon; and on this theory Toaldo draws the following consequences: 1*st*, The seasons and constitution of the year should have a period nearly equal to the revolution of the moon's apogeum, which is from eight to nine years. 2*dly*, About the middle of this period, which is from four to five years, there ought to be a return, which should bring with it most frequently extraordinary seasons. By observations during a considerable length of time, he found the amount of the quantities of rain for nine successive years to be always equal or nearly so both at Padua and at Paris. Toaldo seems to think this opinion is confirmed, by finding that the moon's apses return to their former situation after eight or nine years; and it is therefore probable, that at these different periods, similar seasons will return. The situation of the apses is the same at the equinoxial and solstitial periods every four years; it may therefore happen, that the fourth year shall resemble one of the former, and that, after an extraordinary season, the fourth succeeding may be expected to be so likewise: but, nevertheless, Toaldo lays most stress on the doctrine of similar seasons returning every eighteen or nineteen years; and in this he is followed by Pere Cotte, M. Fouchy and Van Swinden; but they have been all anticipated by the author of an Essay on Meteorology, published in London 1715. Hoffman likewise remarked a striking coincidence in the temperature and humidity of the years 1709 and 1728, which exactly agrees with the observation of Toaldo. Seneca says in his book de Cometis, "Pluviæ quoque et alia tempestatum genera, ad prescriptum revertuntur:" but the precise period discovered by Toaldo is supposed to be indicated in the 18th book, and 25th chapter of Pliny's Natural History; and in the 39th chapter of his second, he evidently ascribes this revolution to a similar cause, in the following words: "Quis enim æstates et hiemes, quæque in temporibus annua vici intelliguntur, siderum motu fieri dubitet? Ergo ut solis natura temperando intelligitur anno, sic reliquorum siderum propria est quibus-que vis, et ad suam cuique naturam fertilis :" and the remainder of the chapter indicates the peculiar influence of several of the planets in this respect: " Saturni maxime transitus imbribus faciunt :" and again, " Arcturi vero sidus non ferme sine procellosa grandine emergit." These documents shew, that a similar opinion has been at all times entertained by the most attentive observers of the operations of nature,—a circumstance which tends greatly to confirm the correctness of Toaldo's theory of this occurrence. The lunar points which are supposed to have the greatest influence in occasioning changes in the weather, are the following: 1*st*, Syzygy or new moon. 2*d*, Syzygy or full moon. 3*d*, The first and second quarters. 4*th*, The Perigee, or greatest proximity of the moon to the earth. 5*th*, The Apogee, or points of greatest distance. 6*th*, The ascending and descending equinoxes, or the passage of the moon over the equator, the first on coming from the south to the north, the second on going from the north to the south. 7*th*, The austral and boreal lunistices, or points corresponding to the extreme position of the moon in the tropics of capricorn and cancer. M. Toaldo adds four other points, which he denominates Octans, being the fourth day before and after each new and full moon: the influence of any of these causes must, however, be greatly increased by being combined with the influence of the sun, when that luminary happens to be in a position corresponding to any of the above. Pere Cotte found a striking resemblance in the temperature of the years corresponding to 1777, being 1701, 1720, 1730, and 1758: and according to the observations of M. Duhamel, there was scarcely any difference of temperature in the different months of the first and last years: the years 1778, 1779, and 1780, were hot and dry, and accorded with years when the same constitution of seasons prevailed. Those which corresponded with 1781 were likewise warm and dry, which it was observed to be in a remarkable degree: the years corresponding to 1782, 1725 and 1763, were singularly cold, moist and late. Cotte supposes, that the period of four or five years mentioned by Toaldo, has also been verified to a certain degree. The following table is drawn up from investigations on this subject, and taken from the works of Pere Cotte.

TABLE *of Lunar Periods of Nineteen Years.*

First Period.	Second Period.	Third Period.	Fourth Period.	Fifth Period.	Sixth Period.	Seventh Period.	Eighth Period.	Ninth Period.	Tenth Period.	Eleventh Period.	Twelfth Period.	Temperature.
1681	1700	1719	1738	1757	1776	1795	1814	1833	1852	1871	1890	Warm and dry.
1682	1701	1720	1739	1758	1777	1796	1815	1834	1853	1872	1891	Variable, moist.
1683	1702	1721	1740	1759	1778	1797	1816	1835	1854	1873	1892	Variable.
1684	1703	1722	1741	1760	1779	1798	1817	1836	1855	1874	1893	Warm and dry.
1685	1704	1723	1742	1761	1780	1799	1818	1837	1856	1875	1894	Warm and dry.
1686	1705	1724	1743	1762	1781	1800	1819	1838	1857	1876	1895	Warm and dry.
1687	1706	1725	1744	1763	1782	1801	1820	1839	1858	1877	1896	Cold and moist.
1688	1707	1726	1745	1764	1783	1802	1821	1840	1859	1878	1897	Mild and dry.
1689	1708	1727	1746	1765	1784	1803	1822	1841	1860	1879	1898	Ordinary.
1690	1709	1728	1747	1766	1785	1804	1823	1842	1861	1880	1899	Cold and moist.
1691	1710	1729	1748	1767	1786	1805	1824	1843	1862	1881	1900	Cold & tolerably dry.
1692	1711	1730	1749	1768	1787	1806	1825	1844	1863	1882	1901	Ordinary cold & moist.
1693	1712	1731	1750	1769	1788	1807	1826	1845	1864	1883	1902	Cold and moist.
1694	1713	1732	1751	1770	1789	1808	1827	1846	1865	1884	1903	Rather cold & moist.
1695	1714	1733	1752	1771	1790	1809	1828	1847	1866	1885	1904	Ordinary.
1696	1715	1734	1753	1772	1791	1810	1829	1848	1867	1886	1905	Ordinary.
1697	1716	1735	1754	1773	1792	1811	1830	1849	1868	1887	1906	Cold and dry.
1698	1717	1736	1755	1774	1793	1812	1831	1850	1869	1888	1907	Variable, moist.
1699	1718	1737	1756	1775	1794	1813	1832	1851	1870	1889	1908	Warm and dry.

The above table is so very simple in its application, that no particular explanation of it seems requisite; and it may be implicitly relied on, so far as experience of former seasons, and the justness of the principles upon which it has been formed, are correct; though, as the observations from which the table was drawn up, were made upon the continent, they may not exactly correspond with the seasons in Britain. From a series of observations continued from the 1769 to the 1777, Pere Cotte found, that of all the lunar points, the austral lunistice is that which has the greatest effect upon the temperature, and upon the atmosphere in general: That an east wind almost always accompanies the lunar points: That the lunar points bring usually a greater degree of cold than heat: That the descending equinox ushers in fine weather; the apogee dull weather; the new moon, clouds; the full moon, the first quarter, and the perigee, rain; the last quarter, the perigee, wind; the boreal lunistice, and the last quarter, fog; the first quarter, and the new moon, thunder; new moon, the aurora borealis. M. Delamark informed Cotte, that he had perceived a remarkable correspondence between the decline of the moon and the winds; that when the moon passes from the boreal to the austral lunistice, the wind gets north, the weather fine, with a high barometer; and when it goes from the austral to the boreal lunistice, the wind becomes south, sometimes stormy, with rain, and the barometer low.

According to Toaldo's observations, storms occur almost always at some of the lunar points, combined or separately. The following is a table of their proportions.

Lunar Points.	Proportion.
New moon, with the perigee,	33.1
New moon, with the apogee,	7.1
Full moon, with the perigee,	10.1
Full moon, with the apogee,	8.1

By the labours of forty years experience, assisted and corroborated by calculations formed by the meteorological journals of several learned societies, M. Toaldo found, that of all the lunar points, the new moon showed the greatest influence upon the atmosphere, and that the influence of the other lunar points were different from each other, and in the following proportions.

Lunar Points.	Proportion.
New moon, ...	6.1
Full moon, ...	5.1
1st quarter, ...	2½.1
2d quarter, ...	2½.1
Perigee, ...	7.1
Apogee, ...	4.1
Ascending equinox, . .	3¼.1
Descending equinox, . .	2¾.1
Austral lunistice, . . .	3.1
Boreal lunistice, . . .	2¾.1

When the moon and sun exert their attractions, either conjunctly, or in opposite directions, their influence will be so uniform upon the atmosphere, being nearly equal, that its effects will not be so remarkable; but when the moon's position is so far altered with respect to the sun, their spheres of attraction must be in that case exerted in an oblique direction; and their influence will be then more obvious, being more irregular.

The following Meteorological Aphorisms, drawn up by the same author, are subjoined in illustration of his theory.

1. When the moon is in conjunction, in opposition, or in quarter with the sun, or in one

of its apses, or in one of the four cardinal points of the zodiac, it is probable that it will produce a sensible alteration on the atmosphere, and a change of weather.

2. The most powerful lunar points are the new and full moon, or the apses.
3. The combination of syzygies with the apses are very powerful; but the new moon with the apses, carries always a moral certainty of a great commotion in the air.
4. The other minor points also acquire great force by their union with the apses.
5. The new and full moon, which does not change the weather, are then most distant from the apses.
6. The fourth day before and after new and full moon, is remarkable in its effects on the weather, and is the point of all others most relied upon by the ancient Egyptians.
7. If the horns of the moon are distinct and well pointed on that day, it shews, that the atmosphere does not contain any vapours in mass; and we may therefore expect that the weather will be fine, till the fourth day before full moon, sometimes through the whole month: but an opposite state of weather may be expected, if the horns are obscure.
8. A lunar point often causes an alteration in the atmosphere, different from its former condition.

9. The apogee, the quarters, the south lunistice, bring commonly good weather. The other points tend to render the gravity of the air less, and thus cause bad weather, by assisting the precipitation of vapour.

10. The most powerful points, that is the new and full moon, the apogee, and above all the perigee, and their combinations, produce storms about the equinoxes and solstices.

11. A change of weather rarely occurs on the day of a lunar point, sometimes it precedes, at other times it follows it.

12. In general, during the six winter months, the tides of the ocean, and the air, anticipate the lunar points, and are stronger: these are occasioned by the perigee of the sun, which approaches the earth about two millions of miles. And in the summer the tides are less, and succeed the lunar points.

13. In the new and full moon, about the equinoxial, and frequently even the solstitial periods, (chiefly in winter), the weather fixes for three or six months, either for good or bad. M. Monier has ascertained, that when the moon passes the meridian, either above or below the horizon, it causes an east wind, or a west wind with rain: this happens oftenest at the new and full moon, when the sun and moon are most distant from the plain of the equator: at such times, if the wind be

east, dry weather sets in, if from the west, the season will be wet.

14. The seasons, tides, and years, appear to have a period of from eight to nine years, according with the revolution of the lunar apses, another of eighteen or nineteen years, and others of still longer periods.

15. There is even a period from four to five years, and these four or five years are liable to bad seasons.

16. Rains and wind begin or cease about the time the moon rises or sets, or that of his passage over the meridian, either above or below, that is at the time the tide begins to make in Italy.

17. It rains more through the day than at night, and oftener in the evening than the morning.

18. Hurricanes blow generally from a point one-fourth less west; this holds as far as the American Islands: but Toaldo has seen a storm from the east; it happened in the morning. And Cotte thinks, that storms usually blow from the point of the horizon where the sun happens to be.

Although the influence of the moon in occasioning changes of the weather, is confirmed by the observations of mankind in every age, these may not perhaps be found every where exactly as in the above aphorisms; besides, they will in general require to be confirmed by experience in every country. Though the term of nineteen years is marked as the corresponding period, it is to be observed, that the astronomical period of the moon's correspondence, is eighteen years and eleven days; and Toaldo uniformly found a remarkable change of weather about that time: but it is in consequence of the change of weather rarely coinciding with the exact lunar point, that causes the variation.

Many of the prognostic signs we have enumerated, do not admit of an interpretation, in the present state of our knowledge of the properties of the atmosphere. Some of them, however, may be explained on the doctrines laid down in the preceding pages: but although the greater number can only be regarded as isolated facts, they evidently depend on the regular operation of certain causes; and considering the ingenuity and talents of those employed in the research, and the great improvements the science of meteorology has received within these few years, a progressive elucidation of every circumstance connected with this subject may be reasonably expected.

END OF VOLUME FIRST.

their Causes, and Indications of Cure, by Robert Bree, M. D. F. R. S. Fellow of the Royal College of Physicians: the 4th Edition, with addition Practical Observations; in 8vo. price 8s. boards

BUTTER's (Dr. William) ACCOUNT of PUERPERAL FEVERS, as they appeared in Derbyshire and some of the Counties adjacent, illustrated by Cases and successful Methods both of Prevention and Cure, 2s. 6d.

BUTTER's IMPROVED METHOD of OPENING ARTERIES. Also, a new Operation for extracting the Cataract. With Cases and Operations, illustrating the good Effects of Arteriotomy, Hemlock, and other Remedies in various Diseases, 3s. 6d.

BUTTER's TREATISE on the ANGINA PECTORIS, 2s.

BUTTER's TREATISE on the VENEREAL ROSE, commonly termed the Gonorrhœa Virulenta, containing a simple, safe, and certain Method of Cure, without the use of Mercury, 2s. 6d.

BUTTER on the INFANTILE REMITTENT FEVER, commonly called the Worm Fever; accurately describing that fatal Disease, explaining its Causes and Nature, and discovering an easy, safe, and successful Method of Cure, 2d edition, 1s. 6d.

BADHAM's OBSERVATIONS on the INFLAMMATORY AFFECTIONS of the MUCOUS MEMBRANE of the Bronchiæ, comprehending an Account of the Acute Inflammation of the Parts—of Peripneumonia Notha, and of Chronic Coughs, &c. by Charles Badham, M. D. Lecturer on the Practice of Physic, &c. and Physician to the Westminster General Dispensary, boards, 4s. 12mo.

CLARK's (John) OBSERVATIONS on the DISEASES which prevail in LONG VOYAGES to HOT COUNTRIES; particularly to the East Indies; and on the same Diseases as they appear in Great Britain, 8vo. boards, 7s. 6d. 1809

CURSORY REMARKS on CORPULENCE.—By a Member of the Royal College of Surgeons, sewed, 2s. 8vo.

> Think not, ye Candidates for health.
> That ought can gain the wish'd-for prize;
> (Or pill or potion, power or wealth,)
> But temperance and exercise.

CARMICHAEL's (Richard) ESSAY on the NATURE of SCROFULA, with Evidence of its Origin from Disorders of the Digestive Organs; illustrated by a number of Cases successfully treated, and interspersed with Observations on the General Treatment of Children, 8vo. boards, 5s.

CARMICHAEL's ESSAY on the Effect of Carbonate and other Preparations of Iron, upon CANCER; with an Inquiry into the Nature of that and other Diseases, to which it bears a relation. By Richard Carmichael, Surgeon, 2d edit. considerably enlarged and improved, boards, 10s. 6d. 8vo.

CUTHBERTSON's PRACTICAL TREATISE on ELECTRICITY and GALVANISM, by John Cuthbertson, Philosophical Instrument Maker, and Member of the Philosophical Societies of Holland and Utrecht, in one vol. 8vo. illustrated with nine copper-plates, boards, 10s. 6d.

CRICHTON's SYNOPTICAL TABLE of DISEASES, exhibiting their Arrangement in Classes, Orders, Genera, and Species, designed for the Use of Students, on two sheets, imperial folio, 2s. 6d.

COPELAND's (Thomas) OBSERVATIONS on some of the principal DISEASES of the RECTUM and ANUS; particularly Stricture of the Rectum, the Hæmorrhoidal Excrescence, and Fistula in Ano, boards, 5s. 8vo. 1810.

CROWTHER's PRACTICAL OBSERVATIONS on the DISEASE of the JOINTS, commonly called WHITE SWELLING; with some Remarks on Caries, Necrosis, and Scrophulous Abscess; in which a new and successful Method of treating these Diseases is pointed out. Second edition, with considerable additions and improvements. By Bryan Crowther, Member of the Royal College of Surgeons in London, and Surgeon to Bridewell and Bethlem Hospitals.—In one volume 8vo. illustrated with seven coloured plates, 10s. 6d. boards, 1808.—Ditto, large paper, with proof impressions of the plates, 16s.

A. CORN. CELSI DE MEDICINA Libri Octo quibus accedunt, Indices Capitum Autorum et Rerum ex Recensione Leonardi Targæ. In 8vo. boards, 12s.

COUPER's SPECULATIONS on the MODE and APPEARANCES of IMPREGNATION in the HUMAN FEMALE; with an Account of the Principal Ancient, and an Examination of the Modern Theories of Generation: the Third edit. with considerable additions, 4s.

DUFOUR's TREATISE on DISEASES of the URETHRA, particularly describing the various Symptoms attending Strictures, Obstructions, Gleets, &c. and on the Prevention of Stone and Gravel, with a Variety of Cases, tending to shew the Efficacy of Daran's Medicated Bougies, and a new Method of treating a Gonorrhœa, &c. 7th edition, 3s.

DAUBENTON's OBSERVATIONS on INDIGESTION, in which is satisfactorily shewn the Efficacy of Ipecacuanha, in relieving this, as well as its connected Train of Complaints peculiar to the Decline of Life; translated from the French, 3d edit. with additions by Dr. Buchan, 1s. 6d. 1809.

DOMEIER's (William) OBSERVATIONS on the Climate, Manners and Amusements of MALTA, principally intended for the information of Invalids repairing to that Island for recovery of Health; by William Domeier, M.D. of the Royal College of Physicians, London, boards, 4s. 6d. 1810.

EARLE's (Sir James) LETTER, containing some Observations on the Fractures of the Lower Limbs; to which is added, an Account of a Contrivance to administer Cleanliness and Com fort to the Bed-ridden, or Persons confined to Bed by Age, Accident, Sickness, or any other Infirmity, with Explanatory Plates, sewed, 3s.

EARLE's (Sir James) OBSERVATIONS on HÆMORRHOIDAL EXCRESCENCES, 2d edition, sewed, 1s. 6d.

FORD's OBSERVATIONS on the DISEASE of the HIP JOINT; to which is added, some Remarks on White Swellings of the Knee, the Caries of the Joint of the Wrist, and other similar Complaints. The whole illustrated by Cases and Engravings, taken from the Diseased Part. By the late Edward Ford, Esq. F.S.A. The second edition, revised carefully, with some additional Observations by Thomas Copeland, Fellow of the College of Surgeons, and Assistant Surgeon to the Westminster General Dispensary. Illustrated with 8 copper-plates, 8vo. boards, 12s 1810.

GRIFFITH's PRACTICAL OBSERVATIONS on the CURE of HECTIC and SLOW FEVERS and the PULMONARY CONSUMPTION; to which is added, a Method of treating several Kinds of Internal Hemorrhages, a new edition, sewed, 1s. 6d.

GRAVES's CONSPECTUS of the LONDON, EDINBURGH, and DUBLIN PHARMACOPŒIAS; wherein the Virtues, Uses and Doses of the several Articles and Preparations contained in those Works are concisely stated; their Pronunciation, as to Quantity, is correctly marked; and a variety of other Particular respecting them given; calculated more especially for the use of Junior Practitioners. By Robert Graves. M. D. 18mo. 4s. 6d.

GIRDLESTONE on DIABETES, with an Historical Sketch of that Disease, sewed, 2s. 6d. 8vo.

GORDON's (Dr. Alexander) TREATISE on the EPIDEMIC PUERPERAL FEVER of ABERDEEN; sewed, 2s. 6d.

GEOGHEGAN's COMMENTARY on the TREATMENT of RUPTURES, particularly in a State of Strangulation. By Edward Geoghegan, Member of the College of Surgeons, and Honorary Member of the Royal Medical Society, Edinburgh; 8vo. bds. 4s. 1810—"This work will be found highly interesting, as it proposes important improvements in the treatment."

GOURLAY's OBSERVATIONS on the NATURAL HISTORY, CLIMATE, and DISEASES of MADEIRA, during a Period of Eighteen Years. By William Gourlay, M. D. Fellow of the Royal College of Physicians, Ebinburgh; and Physician to the British Factory of Madeira; 8vo. boards, 6s. 1810.

HARTY's (Dr.) OBSERVATIONS on the SIMPLE DYSENTERY, and its COMBINATIONS; containing a Review of the most celebrated Authors who have written on this subject, and also an Investigation into the source of Contagion in that and some other Diseases, boards 7s. 6d. 8vo.

"This Work we find no difficulty in recommending to our Readers; it contains, unquestionably, a larger mass of evidence than is any where else to be found of the various species of this formidable disease; and again we think it right once more to recommend the Work before us, as the most valuable digest of all that has been written upon it."---Vide Medical and Physical Journal, for December, 1805.

"We have derived much gratification from the perusal of this volume, since, without going the complete length of all his speculations, we think that the Author has manifested a considerable share of ability in their support; he merits the praise of sagacity, for the selection and arrangement of his materials; of great industry, in the collection of them; and of having manifested a becoming modesty in the enunciation of his own conjectures."--Vide Monthly Review, for June, 1806.

HUNTER's (John) TREATISE on the VENEREAL DISEASE, with an Introduction and Commentary, by Dr. Joseph Adams, boards, 14s. 8vo.

HAMILTON's OBSERVATIONS on SCROFULOUS AFFECTIONS, with Remarks on Scirrhous Cancer, and Rachitis, boards, 3s. 12mo.

HIGGINS's (William) ESSAY on the THEORY and PRACTICE of BLEACHING, wherein the Sulphuret of LIME is recommended as a Substitute for Pot-Ash, sewed, 2s.

HASLAM's (John) OBSERVATIONS on MADNESS and MELANCHOLY: including Practical Remarks on those Diseases: together with Cases, and an Account of the Morbid Appearances on Dissection; by John Haslam, late of Pembroke Hall, Cambridge; Member of the Royal College of Surgeons, and Apothecary to Bethlem Hospital, 2d edition, considerably enlarged, in one vol. 8vo. boards, 9s.

JOHNSON's PRACTICAL ESSAY on CANCER, being the Substance of Observations, to which the Annual Prize for 1808, was adjudged by the Royal College of Surgeons, London; by Christopher Turner Johnson, Surgeon, of Exeter, Member of the Royal College of Surgeons, London, and of the Royal Medical Society of Edinburgh, 8vo. boards, 5s. 6d. 1810.

IDENTITIES ASCERTAINED; or, an Illustration of Mr. Ware's Opinion respecting the sameness of Infection in Venereal Gonorrhœa, and the Opthalmia in Egypt: with an Examination of Affinity between ancient Leprosy and Lues, 2s. 6d. 8vo. 1808.

KEATE's CASES of the HYDROCELE and HERNIA INCARCERARA, sewed, 1s. 6d.

LIND on DISEASES incidental to EUROPEANS in HOT CLIMATES, with the Method of preventing their fatal Consequences; the sixth Edition, in one volume octavo, price 8s. boards, 1808.

LAWRENCE (William) TREATISE on RUPTURES, containing an Anatomical Description of each Species; with an Account of its Symptoms, Progress, and Treatment, illustrated with plates. By William Lawrence, Member of the Royal College of Surgeons, and Demonstrator of Anatomy, at St. Bartholomew's Hospital, in large 8vo. 10s. 6d. boards, 1810.

LONDON DISSECTOR; or, System of Dissection practised in the Hospitals and Lecture Rooms of the Metropolis: explained by the clearest Rules, for the Use of the Students. Comprising a Description of the Muscles, Vessels, Nerves, and Vis-

ciples and Practice of Surgery, 2d edition, with Additions, 7s. 8vo.

POTT's CHIRURGICAL WORKS, 3 vol. 8vo. new, boards, 18s. 1783.—N. B. The above is the last edition Mr. Pott ever lived to publish.

POTT's CHIRURGICAL WORKS, a new Edition, with his last Corrections; to which are added, a short Account of the Life of the Author, a Method of curing the Hydrocele by Injection, and occasional Notes and Observations, by Sir James Earle, F. R. S. Surgeon Extraordinary to the King, &c.—3 vol. boards, £1. 7s. 1808.

ROYSTON's OBSERVATIONS on the RISE and PROGRESS of the MEDICAL ART in the BRITISH EMPIRE, containing Remarks on Medical Literature, and a View of a Bibliographia Medicinæ Britannicæ, by W. Royston, 2s.

RICHERAND's ELEMENTS of PHYSIOLOGY; containing a comprehensive View and clear Explanation of the Functions of the Human Body, in which the modern Improvements in Chemistry, Galvanism, and other Sciences, are applied to explain the Actions of the Animal Economy, with a new Classification and copious Index; translated from the French of A. Richerand, Professor of Anatomy and Physiology, and principal Surgeon to the Hospital of the North, in Paris. By Robert Kerrison, Member of the Royal College of Surgeons in London, &c. In one closely printed vol. 8vo. 6s. boards, 1806.

REES's (Dr. George) OBSERVATIONS on DISEASES of the UTERUS; in which are included, Remarks on Moles, Polypi, and Prolapsus, as also on Scirrhous and Cancerous Affections of that Organ, boards, 4s. 6d. 8vo.

REES's (Dr. George) TREATISE on the PRIMARY SYMPTOMS of LUES VENEREA, with a concise, critical, and chronological Account of all the English Writers on this Subject, from 1735 to 1783; to which is added, an Analysis of a Course of Lectures delivered by the Author, boards, 5s. 8vo.

ROLLO's CASES of the DIABETES MELLITUS, with the Results of the Trials of certain Acids and other Substances in the Cure of the Lues Venera, 2d edition, with large Additions, boards, 6s. 8vo. 1806.

RICHTER's MEDICAL and SURGICAL OBSERVATIONS, 8vo. 5s.

RYDING's VETERINARY PATHOLOGY, or, a Treatise on the Cure and Progress of the Disease of the Horse, &c. &c. and an Appendix, or Veterinary Dispensatory, &c. boards, 3s. 6d. 8vo.

SMITH's ESSAY on the CAUSES of the VARIETY of COMPLEXION and FIGURE in the HUMAN SPECIES; to which are added, STRICTURES on LORD KAIMES's DISCOURSE of the ORIGINAL DIVERSITY of MANKIND, boards, 3s. 6d.